DEVELOPMENT OF A SYSTEMATIC APPROACH FOR KNOWLEDGE ACQUISITION AND EXPERIENCE CAPTURE OF VETERAN PRACTITIONERS IN THE HIGHWAY CONSTRUCTION INDUSTRY

By
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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Dedicated to Jim

EPSTEIN

JAMES (JIM) TAYLOR, a great lover of people and music, passed away peacefully at the age of 40, on Aug. 10, 1995. He has gone on to join his mother, Edie, and is survived by wife Jill, son Justin, father David, brothers Bill and Bob, and sister Carolan, and other loving family members and friends. Graveside Services to be held Sunday.

Jim,

Only the good die young, and you my brother were the absolute very best. Say HI to mom, and remember always, that I love you forever.

With all my heart and soul,

Bill

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By

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Chairman: Dr. Zohar J. Herbsman
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Major Department: Civil Engineering

Every company in every industry faces the prospect of the loss of knowledge and experience through the departure of key personnel. This predicament created by the loss of veteran employees is especially acute in the highway construction industry, where frequently the experience is either undocumented or poorly documented, and the knowledge possessed by these people is retained exclusively as personal property. This dissertation not only explores the difficulties associated with pursuing an approach to acquire heretofore undocumented construction knowledge and expertise, but it also recognizes the vast amounts of highway construction data and information that are currently available within the transportation industry. Any concerted effort attempting to capture the construction knowledge and expertise of a large organization, such as a department of transportation, would be severely remiss in not taking advantage of this existing base of documented information.

This research endeavor represents a comprehensive study of the problems associated with the development of a systematic approach for capturing the knowledge and experience of a large organization, and establishing a computer delivery system for dissemination of this encoded information. Fundamental to this delivery system is the creation of a user-friendly computing environment that will provide an intuitive tool capable of assisting both veteran and novice practitioners in fashioning more informed decisions concerning problems that may arise during normal and abnormal highway construction operations.

One of the major accomplishments of this research effort, was the development of an information management prototype system which was given the name IN REACH (Intelligent iNformation Retrieval and Expert Advice for the Construction of Highways). IN REACH is comprised of an underlying, fully functionally hypertext network which is augmented by the integration of some innovative database management and expert systems strategies. In an effort to add structure to the inherently unstructured world of a pure hypertext system, IN REACH utilizes these integrated strategies to enhance the user's capability of direct queries to the overall network, both statically and dynamically.

CHAPTER 1
INTRODUCTION

1.1 General Comments

Like many other general concepts, knowledge is a difficult term to quantify. A good discussion of what constitutes knowledge should begin with characterization of the difference between data and information. Commonly speaking, raw data are nothing more than a collection of facts and figures, that by themselves lack any real significance. Only when meaning is assigned to these facts and figures do these data evolve into information. Knowledge, on the other hand, can be thought of as the cognitive storage of information which is readily available for retrieval by the conscious human mind. Feigenbaum [1984] makes a very interesting point about the relationship between knowledge and information. He suggests that first it should be clarified that knowledge is not synonymous with information, rather knowledge is information that has been implemented, categorized, applied. According to Hayes-Roth, Waterman and Lenant [1983], knowledge consists of (1) symbolic descriptions of definitions, (2) symbolic descriptions of relationships, and (3) procedures to manipulate both type of descriptions.

Knowledge of a certain subject, in and of itself, does not constitute expertise in that field. Expertise is a function of the skillful application of knowledge, and this skill is a direct result of having experience in that particular domain. What differentiates a novice from an

expert is not the quantity of knowledge possessed, but rather the amount of experience using that knowledge. More than ever, modern industry depends on the expertise of its work force for success. No longer in today's complex world, can one man or woman possibly know everything there is to know.

For an organization to prosper in this environment, not only must its members possess a certain level of expertise on an individual basis, but this personal expertise must be exchanged and transferred throughout the entire structure of the group. The wealth of knowledge and experience accumulated by veteran employees through their years of service is something which clearly should be utilized and taken advantage of for current operations. Furthermore, the fact that these veteran personnel will not remain with the organization into perpetuity suggests that, as is the case with any limited and valued possession, their knowledge and experience must be captured and stored for future use.

1.2 Problem Statement

The research effort presented herein is focused upon the United States highway construction industry from the perspective of the governmental state highway agencies (SHAs). Every state in this country has a representative SHA which is responsible for the construction of the transportation systems within their boundaries. Not unlike any other large organization, SHAs continually face the unfavorable prospect of losing significant amounts of accrued knowledge and experience as a result of ongoing departures of key personnel. These veteran employees, many of whom have spent their entire professional careers under the employ of a single SHA, aggregately represent thousands of years of

accumulated expertise. This predicament is especially acute in the realm of highway construction operations, wherein frequently the knowledge and experience possessed by these people is either undocumented or poorly documented, and is usually retained exclusively as their personal property. What this implies is that, upon their departure, these seasoned practioners will take with them the years of training and experience provided to them by the SHA, and in return leave behind little if any of their knowledge and expertise.

To further exasperate this situation, currently and over the next several years, the SHAs of this country are and will continue to experience an exceedingly concentrated loss of veteran personnel. The reason why this is happening is due to the fact that many key members of today's transportation workforce began their SHA careers during the highway construction boom of the late 1960s and early 1970s, and unfortunately they are all approaching retirement age at approximately the same time. This inevitable occurrence is going to create a critical shortage of experienced practitioners. Time is therefore of the essence for implementation of some sort of capture program that will not allow a whole generation of highway construction experience to disappear. Failure to capture this expertise and integrate it into the organizational and operational structures of the various SHAs will result in an enormous loss of knowledge that may never fully be replaced. Being that experience is such a valuable asset in the field of highway construction, research into a methodology for securing this resource for future use is certainly a very practical and worthwhile endeavor.

In conjunction with the development of a functional means of acquiring heretofore undocumented construction expertise, recognition of the vast amounts of highway construction data and information currently available within the transportation industry is

fundamental. Over the years, SHAs across the country have produced a wealth of quality programs and publications presenting a variety of construction related topics. Any concerted effort attempting to capture the highway construction knowledge and experience of this country's SHAs would be severely remiss in not taking advantage of this existing base of documented information.

Along with preserving potentially irreplaceable construction expertise and utilizing existing data and documentation, the other critical aspect of a successful experience capture program is the proposed method of disseminating the acquired information. This information and the knowledge associated with this information must first be formalized and encoded into some sort of communicable form. Then, through a computerized storage, management and retrieval system, novice and veteran personnel alike would be able to easily refer to all available information about a particular subject. This easy access to a wide variety of related topics would provide the user a powerful tool from which to gather the appropriate knowledge necessary for a more informed decision making process.

1.3 Research Objectives

1.3.1 General Comments

The overall goal of this research project was to develop a systematic approach for gathering highway construction knowledge and experience, organizing this information, storing it, and presenting it in such a fashion as to be readily accessible and useful to anyone wishing to benefit from this knowledge base. This broad effort can be broken down into the following research objectives as presented next.

1.3.2 Breakdown of the Research Objectives

1.3.2.1 Objective 1

The initial objective of this research was to identify and prioritize the general categories of highway construction work and operations wherein the loss of experience was felt to be most critical. The area distinguished as most acute was then focused upon for further concentrated research.

1.3.2.2 Objective 2

Having determined the area of focus, the next objective was to identify and analyze existing programs and published materials related to this selected field of concentration. The appropriate information was then categorized and stored for incorporation into the final system.

1.3.2.3 Objective 3

A fundamental objective of this research was the development of a systematic approach for capturing and documenting the individual knowledge and experience of veteran personnel. This information was then combined with the data as collected from Objective 2 to create an integrated base of individual and organizational highway construction knowledge.

1.3.2.4 Objective 4

Having a functional knowledge base from which to draw from, the final objective was the generation and subsequent prototype testing of the computerized delivery system. Key to the creation of a useful and flexible information management system, was the development

of a highly intuitive and user-friendly environment that allows for relatively easy future expansion to the basic system architecture.

1.4 Research Methodology

1.4.1 General Comments

At this point it should be noted that this dissertation is based on funded research conducted for the Florida Department of Transportation (FDOT). As such, the data and information collected and analyzed typically relate to FDOT highway construction operations. Although this research effort concentrated on FDOT personnel and documentation, any organization could utilize this basic approach in its generic form simply by focusing the knowledge base development process on the needs specific to that organization. Work on this particular study consisted of accomplishing the following phased tasks, and is further illustrated by the schematic flowchart presented in Figure 1.1.

1.4.2 Breakdown of the Research Methodology Phases

1.4.2.1 Phase 1

Several preliminary interviews with various members of the FDOT were conducted as a means of developing a comprehensive questionnaire that would fully address the issue of knowledge acquisition and experience capture within the highway construction industry. The resulting survey was then distributed to all SHAs in the United States, with the exception of Florida, as well as to each of the Canadian provincial highway agencies. In Florida, rather then mail the survey directly to the central state office in Tallahassee, it was sent out individually to each district office. Conclusions drawn from all returned questionnaires were

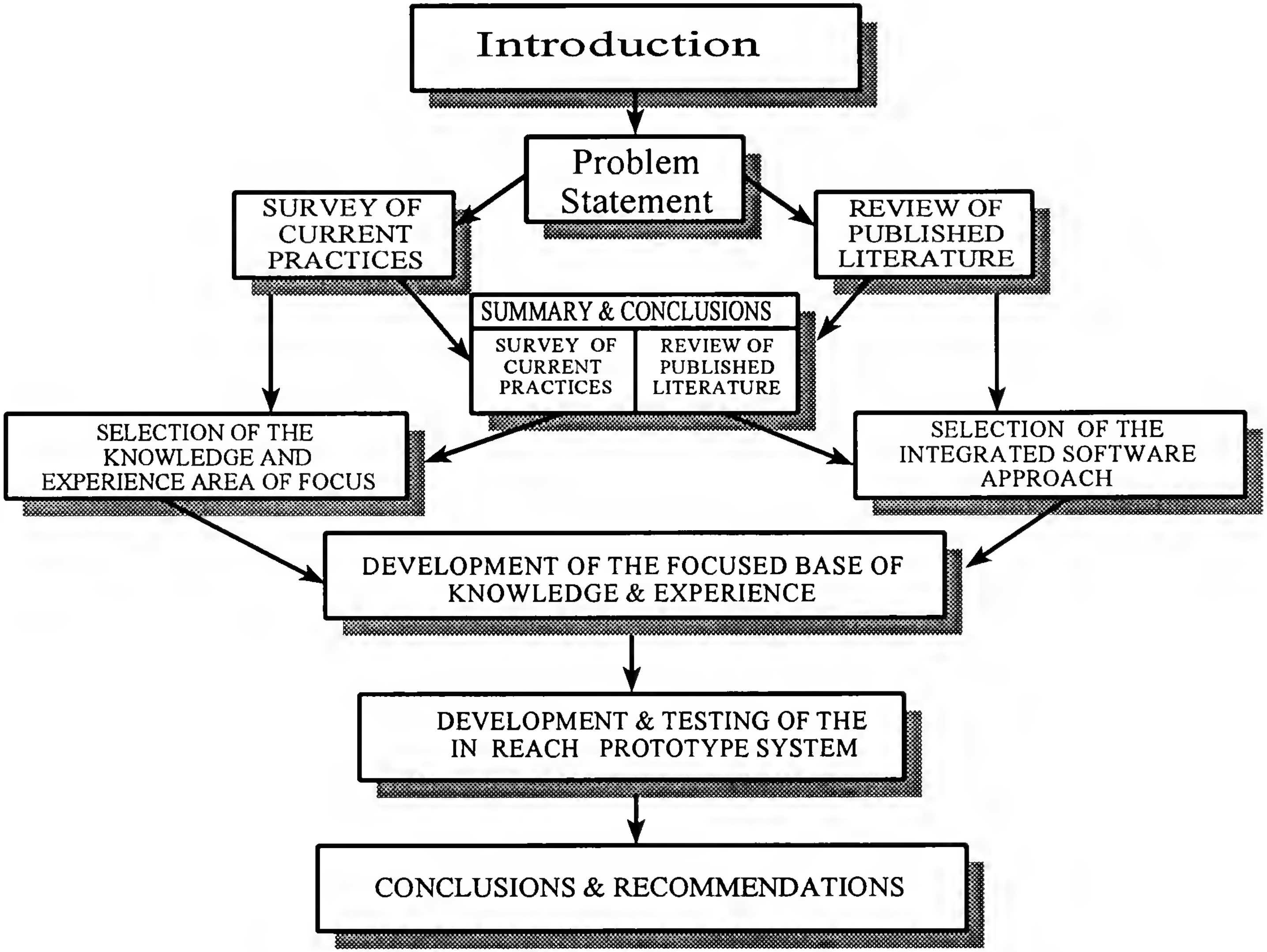


Figure 1.1 - Research Development Flowchart

then used to identify the most acute area of highway construction operations for further concentrated research.

1.4.2.2 Phase 2

An extensive literature search was performed through a variety of state-of-the-art electronic databases, in an attempt to uncover the most up-to-date literature written on this subject. In addition to reviewing current publications, portions of the questionnaire from Phase 1 were utilized to ascertain the level of similar endeavors that may be underway within the different American and Canadian highway agencies. Furthermore, additional efforts were made to communicate with other governmental and private organizations to identify the possible existence of any type of knowledge acquisition and experience capture programs that these contacted organizations may be implementing.

1.4.2.3 Phase 3

Once the area of focus was selected, as described in Phase 1, a detailed review of all related FDOT documentation was effected. Numerous FDOT publications were accumulated, and selected information from these documents was then electronically stored as the foundation on which the final computer delivery system would be built.

1.4.2.4 Phase 4

The next phase was the development and implementation of a systematic approach for capturing the undocumented experience possessed by veteran construction personnel. Initially, as is standard with most knowledge acquisition programs, interviews with various domain experts in the identified area of concentration were conducted. It was soon

discovered that although informative and useful in shaping the direction of the study, these sessions were relatively inefficient for the task at hand, and the comments obtained were often vague and unfocused . Further into the research, a format for Post Construction Conferences (PCC) was developed, wherein comments made by the field personnel specific to a particular job could be integrated into the preliminary knowledge base that was being compiled in Phase 3. Due to the fact that these meetings were centered around construction related topics specific to the job that these people were currently working on, their recollections and comments tended to be more thorough and useful. Additionally, the goal of a systematic knowledge acquisition technique was more closely realized because the proposed PCC approach minimized personality influences that are inherent in typical one-on-one interview sessions.

1.4.2.5 Phase 5

Critical to the success of this project was the identification of the requirements of the end user. Throughout the research process, close contacts with many key FDOT construction personnel were maintained in order to establish the specific departmental needs that the final prototype computer delivery system must address. Conclusions drawn from the survey of current practices and the literature review from Phase 2, coupled with a functional understanding of the needs of the FDOT, led to the determination that a hybrid programming environment would be the best platform for the accomplishment of developing a flexible, user-friendly information management and retrieval system. The established independent software technologies of expert systems, hypertext, and database management systems were utilized in creating an integrated computer program entitled IN REACH, which

is an acronym for "Intelligent iNformation Retrieval and Expert Advice in the Construction of Highways."

1.4.2.6 Phase 6

Structured demonstration sessions for the presentation of preparatory versions of the IN REACH program were organized for testing and validation purposes. Additionally, executable files containing preliminary editions of IN REACH were distributed to selected FDOT personnel for their unsupervised use. Comments and suggestions collected from these different testing methods were evaluated and incorporated into the final IN REACH prototype system.

1.4.2.7 Phase 7

Results from the total research effort encompassing Phase 1 through Phase 6 were analyzed, and a final dissertation presenting these findings was prepared.

CHAPTER 2
SURVEY OF CURRENT PRACTICES

2.1 Survey of Governmental Highway Agencies

2.1.1 Introduction

As previously noted in Chapter 1, the initial objective of this research was to identify and prioritize the general categories of construction work and operations wherein the loss of experience was felt to be most critical from the perspective of governmental highway agencies. To this end, several preliminary interviews were conducted with a number of FDOT Construction and Resident Engineers. These sessions were instrumental in gaining a better understanding of the problem as seen from the viewpoints of typical SHA construction personnel. From these interviews, a comprehensive "Knowledge Acquisition and Experience Capture" (KA & EC) questionnaire was developed for distribution to the various state and provincial highway agencies throughout the United States and Canada. A copy of this survey along with a generic cover letter are included in this dissertation as Appendix A.

2.1.2 Breakdown of the KA & EC Questionnaire

2.1.2.1 Section I--Loss of Veteran Employees

The function of this section of the survey was twofold. One purpose was to determine the level of importance that the different agencies placed on the loss of expert

knowledge due to the departure of veteran employees from the organization. The other purpose served by this section was the quantification of the magnitude of loss with respect to each agency.

2.1.2.2 Section II--General Categories of Construction Work

Section II was designed as a way to numerically measure the effect that the loss of experience has on different general categories of highway construction work. From the developmental survey interviews conducted with the FDOT, the following five major categories of construction work were identified for inclusion into the survey:

1) Bridge Work
2) Roadway Work (other than asphalt)
3) Asphalt Work
4) Signaling and Lighting
5) Maintenance of Traffic

The categories of Bridge Work, Roadway Work (other than asphalt), and Asphalt Work were further subdivided into two separate categories, namely new construction work, and maintenance and repair work. Additionally, the respondents were encouraged to list and rate any other general categories of construction work that they deemed appropriate.

2.1.2.3 Section III--General Areas of Construction Operations and Administration

Again from the preliminary interviews conducted with the FDOT, five major areas of highway construction operative and administrative duties were distinguished as those that typical construction personnel are most regularly involved in. These areas are as follows:

1) Constructability Analysis

2) Inspection

3) Quality Control

4) Construction Documentation

5) Departmental Documentation

As was the case with Section II, the respondents were asked to specify and rate any other areas of construction operations and administration that were not listed but may apply to their agency.

2.1.2.4 Section IV--Knowledge Acquisition and Experience Capture Methodology

The final section of the questionnaire was devoted to determining the current existence of, or future development of, techniques by which the various polled highway agencies were attempting to acquire and capture the knowledge and experience of their veteran practitioners. If applicable, upon completion of the collection and capture phases of the particular knowledge acquisition methods listed, the questionnaire also requested that the responding agency please specify what type of system or systems they utilized for storing and distributing this collected information to the appropriate personnel.

2.1.3 Distribution of the KA & EC Questionnaire

Given that the intended focus of the research was to be on FDOT highway construction operations, it was desired to distribute the KA & EC questionnaire in such a fashion as to obtain a set of comparative results between North America in general and the state of Florida in particular. With this in mind, two separate survey packages were sent out. The North American survey package was mailed to the attention of each SHA construction

department in the United States, with the exception of Florida. Additionally, every provincial highway agency in Canada was included in this mailing. In order to contrast these results with those in Florida, this same survey was transmitted to each of the district construction offices within the FDOT. Distribution lists for the North American survey package, as well as the Florida package, are given in Appendix B.

2.1.4 Rates of Response to the KA &EC Questionnaire

The North American survey was distributed to a total of 61 agencies (the 49 SHAs of the United States, excluding Florida; the District of Columbia Department of Public Works; and the 11 Canadian provincial highway agencies). From this mailing, a total of 34 responses were received. Neglecting multiple respondents from a single agency, the North American survey realized an overall response of 28 out of 61 agencies for an approximate rate of 46%. Although this was a relatively low rate of response, it was sufficient to serve the intended purpose of identifying and framing the problem, thus shaping the direction of subsequent research.

In Florida, the questionnaire was distributed to each of the seven FDOT district offices, as well as to the construction office of the Florida Turnpike Authority. It should be noted that copies of the questionnaire were specifically mailed to three different individuals in District 2. This occurred because District 2 served as the main personnel resource center for the research, and as such, there were several people who expressed an interest in participating in the study. From this mailing, 10 responses were received. Using the same elimination approach of multiple responses from a single district, the overall response rate from Florida's district offices was 4 out of 8, which translates to a rate of 50%.

Although the rate of response was again somewhat disappointing, the number of questionnaires received (10) was deemed suitable for deriving comparative results.

2.1.5 Section by Section Results of the KA & EC Questionnaire

2.1.5.1 Section I--Loss of Veteran Employees

Results for Section I from the North American KA & EC questionnaire are summarized in Table 2.1, and those from the Florida survey are presented in Table 2.2. The two numbers to focus on from this section's results are 1) the average value for the "General Rating" of the importance of the loss of experience and 2) the average value of the "Average Years / Person."

The "General Rating," measured on a scale of 1 to 5, with 1 being the lowest level of importance and 5 being the highest, is an indication of the degree of significance the respondent feels that his or her organization places on the loss of knowledge and experience caused by the departure of veteran employees. The average value of this "General Rating" from the North American survey was 3.39, which was slightly higher than the Florida average of 3.20.

The second value that should be highlighted is the "Average Years / Person." This number is important as verification that respondents were approaching the questionnaire from the perspective of veteran personnel only. In other words, the research effort was concerned exclusively with experienced based issues relating to those employees who possessed significant years of service in the highway construction industry, and as such, the survey's intent was to purposely neglect those departing personnel who had not yet accumulated substantial years of industry experience. Referring again to Table 2.1 and Table 2.2, it is

Table 2.1 - Results of the North American Questionnaire (Section I)

SECTION I - LOSS OF VETERAN EMPLOYEES			
Responding District Office	**General Rating**	**Veteran Employees Lost per Year**	**Years of Experience Lost per Year**
Alaska (USA)	3	10	250
Alabama (USA)	2	60	2,100
Arkansas (USA)	3	--------	--------
California (USA)	4	1,000	30,000
Colorado (USA)	4	85	2,550
Connecticut (USA)		20	240
Georgia (USA)	3	195	5,850
Idaho (USA)	4	45	900
Illinois (USA)	5	90	1,765
Kansas (USA)	5	--------	--------
Kentucky (USA)	3	15	500
Louisiana (USA)	1	25	625
Maryland - 1 (USA)	3	14	294
Maryland - 2 (USA)	4	--------	--------
Maryland - 3 (USA)	3	10	325
Maryland - 4 (USA)	4	2	60
Maryland - 5 (USA)	5	2	50
Maryland - 6 (USA)	3	--------	--------
Mississippi (USA)	4	26	650
Missouri (USA)	3	27	960
New York (USA)	4	780	15,600
North Dakota (USA)	4	11	372
Ohio (USA)	2	30	675
Oklahoma (USA)	4	10	300
Pennsylvania (USA)	4	500	10,000
South Dakota (USA)	3	20	400
Tennessee (USA)	4	100	4,000
Texas (USA)	3	500	12,000
Virginia (USA)	3	67	1,807
Wyoming (USA)	5	10	300
Alberta (CAN)	3	143	2,750
British Columbia - 1 (CAN)	3	30	750
British Columbia - 2 (CAN)	2	8	240
Nova Scotia (CAN)	2	11	300
Number of Responses	**33**	**30**	**30**
Average Values	**3.29**	**Average Years / Person = 25.12**	

Table 2.2 - Results of the Florida Questionnaire (Section I)

SECTION I - LOSS OF VETERAN EMPLOYEES			
Responding District Office	**General Rating**	**Veteran Employees Lost per Year**	**Years of Experience Lost per Year**
Florida - District 2	3	15	450
Florida - District 2	1	1	35
Florida - District 2	4	2	65
Florida - District 2	5	-----	-----
Florida - District 2	5	10	330
Florida - District 3	3	3	100
Florida - District 7	3	2	50
Florida - District 7	3	-----	-----
Florida - District 7	3	5	120
Florida - District 7	2	10	300
Number of Responses	**10**	**8**	**8**
Average Values	**3.20**	**Average Years / Person = 30.21**	

apparent from the tabulated results for the "Average Years / Person" values, that both the North American respondents who reported an average of 25.12 years / person, as well as the Florida respondents at an average of 30.21 years / person understood the requirements of the survey and responded accordingly.

2.1.5.2 Section II--General Categories of Construction Work

The values presented in Table 2.3 (North America) and Table 2.4 (Florida) represent the respondents' ratings of the effects of the loss of experience with respect to various general categories of construction work as specified in Section II of the KA & EC questionnaire. Ratings for this section were based on a scale of 1 to 10, with 1 being the lowest level of significance and 10 being the highest. Additionally, Figure 2.1 has been generated as a means of graphically illustrating the average values of the North American survey in comparison with those of the Florida survey.

Table 2.3 - Results of the North American Questionnaire (Section II)

SECTION II - GENERAL CATEGORIES OF CONSTRUCTION WORK

Responding Agency	Bridge New	Bridge R & M	Road New	Road R & M	Asphalt New	Asphalt R & M	Sig & Light	Maint of Traffic	Other (# Only)
Alaska (USA)	-----	-----	-----	-----	-----	-----	-----	-----	-----
Alabama (USA)	6	5	6	5	7	6	7	6	-----
Arkansas (USA)	5	6	4	4	5	3	4	4	1
California (USA)	8	8	7	7	6	6	9	5	2
Colorado (USA)	5	5	5	5	5	5	5	5	-----
Connecticut (USA)	9	9	9	9	9	9	7	9	2
Georgia (USA)	5	6	5	6	7	7	3	4	-----
Idaho (USA)	8	5	9	3	8	4	7	7	1
Illinois (USA)	8	7	7	6	8	6	9	9	-----
Kansas (USA)	10	10	10	10	10	10	7	5	1
Kentucky (USA)	7	8	10	8	7	9	5	5	2
Louisiana (USA)	7	6	5	5	5	5	3	2	-----
Maryland - 1 (USA)	10	6	9	5	8	4	4	7	2
Maryland - 2 (USA)	-----	4	-----	4	-----	4	-----	4	-----
Maryland - 3 (USA)	5	4	5	4	6	5	5	1	-----
Maryland - 4 (USA)	-----	-----	-----	-----	-----	-----	-----	-----	-----
Maryland - 5 (USA)	-----	-----	-----	-----	-----	-----	1	2	3
Maryland - 6 (USA)	-----	-----	-----	-----	-----	-----	-----	-----	3
Mississippi (USA)	8	8	7	8	8	7	8	9	-----
Missouri (USA)	5	5	5	3	5	3	3	3	-----
New York (USA)	8	7	8	7	7	6	6	6	-----
North Dakota (USA)	7	-----	7	-----	7	-----	-----	7	-----
Ohio (USA)	7	6	7	5	5	4	8	5	2
Oklahoma (USA)	9	-----	9	-----	10	-----	-----	-----	-----
Pennsylvania (USA)	10	10	9	9	9	9	7	5	-----
South Dakota (USA)	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tennessee (USA)	8	5	8	5	8	5	4	4	-----
Texas (USA)	9	8	8	7	8	7	8	8	3
Virginia (USA)	8	8	8	8	8	8	1	5	-----
Wyoming (USA)	8	8	10	10	10	10	7	7	-----
Alberta (CAN)	8	10	7	8	6	9	4	3	1
British Columbia - 1 (CAN)	7	6	8	5	7	7	4	8	1
British Columbia - 2 (CAN)	9	1	10	1	5	1	2	2	-----
Nova Scotia (CAN)	6	8	6	9	6	8	7	8	-----
Number of Responses	28	27	28	27	28	27	27	29	13
Average Values	7.50	6.63	7.43	6.15	7.14	6.19	5.37	5.34	N / A

Table 2.4 - Results of the Florida Questionnaire (Section II)

SECTION II - GENERAL CATEGORIES OF CONSTRUCTION WORK

Responding Agency	Bridge New	Bridge R & M	Road New	Road R & M	Asphalt New	Asphalt R & M	Sig & Light	Maint of Traffic	Other (# Only)
Florida - District 2	7	3	-----	-----	-----	-----	-----	-----	-----
Florida - District 2	10	9	10	8	10	8	8	10	2
Florida - District 2	9	3	9	2	8	2	6	8	2
Florida - District 2	9	-----	-----	-----	9	-----	8	9	1
Florida - District 2	8	5	8	5	8	7	5	5	1
Florida - District 3	8	8	7	6	8	5	6	6	-----
Florida - District 7	10	-----	7	-----	8	-----	8	7	4
Florida - District 7	8	-----	8	-----	8	-----	5	5	-----
Florida - District 7	9	10	8	1	7	2	5	6	-----
Florida - District 7	8	8	8	8	8	8	5	7	-----
Number of Responses	**10**	7	**8**	6	9	6	9	9	**5**
Average Values	**8.60**	**6.57**	**8.13**	**5.00**	**8.22**	**5.33**	**6.22**	**7.00**	**N / A**

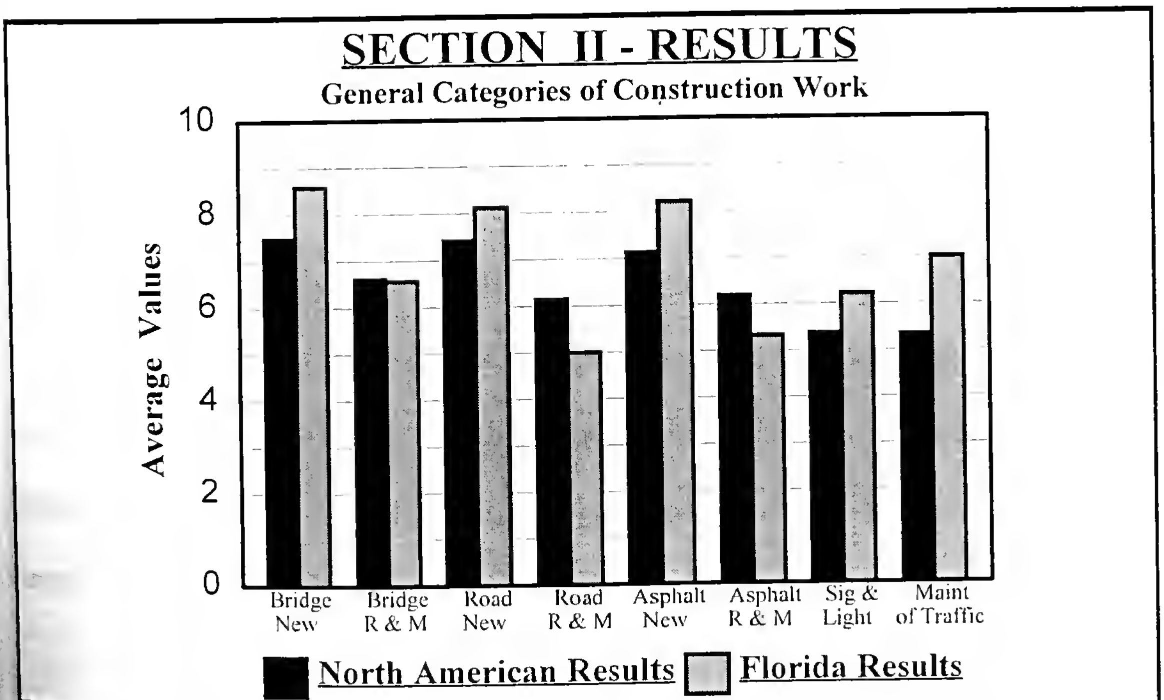


Figure 2.1 - Comparison of Results from North America Versus Florida (Section II)

From Table 2.3, Table 2.4, and Figure 2.1 it can be seen that the loss of experience with respect to new construction work consistently rated as more significant than that of repair and maintenance within the same general category of work. In the North American survey, "Signaling & Lighting" and "Maintenance of Traffic" clearly were perceived as the two specified categories least affected by the loss of experience. Although these two categories on average rated higher in the Florida survey, the level of importance of these categories with respect to the loss of veteran expertise still fell far below those categories associated with new construction work. The column labeled "Other (# Only)" designates other categories of work not specified in the distributed questionnaire. The numbers that appear in this column are not ratings, rather they refer only to how many additional categories were noted by that particular respondent. In the North American survey, the most common "Other" category selected was landscaping. Out of 23 responses on a total of 13 different questionnaires, seven people mentioned landscaping, with an average rating of 6.17. The "Other" category in the Florida survey, on the other hand, showed little consensus of opinion.

2.1.5.3 Section III--General Areas of Construction Operations and Administration

Section III responses are based on the same 1 to 10 rating scale as those from Section II. Results of the North American survey and the Florida survey are summarized in Table 2.5 and Table 2.6, respectively. A histogram that includes both sets of data has again been included as Figure 2.2.

Analysis of the information presented in Table 2.5, Table 2.6, and Figure 2.2 demonstrated that, on average, "Constructability Analysis," "Inspection Operations," and

Table 2.5 - Results of the North American Questionnaire (Section III)

SECTION III - GENERAL AREAS OF CONSTRUCTION OPERATIONS						
Responding Agency	**Constructability Analysis**	**Inspection Operations**	**Quality Control**	**Construct Docs**	**Department Docs**	**Other (# Only)**
Alaska (USA)	-----	8	8	6	5	-----
Alabama (USA)	7	8	8	8	7	-----
Arkansas (USA)	6	5	5	4	3	1
California (USA)	-----	8	9	7	9	-----
Colorado (USA)	8	3	3	5	5	-----
Connecticut (USA)	8	10	9	9	9	-----
Georgia (USA)	8	5	6	4	5	-----
Idaho (USA)	9	8	7	7	7	3
Illinois (USA)	9	8	8	10	10	-----
Kansas (USA)	10	10	10	5	5	1
Kentucky (USA)	10	6	8	5	5	-----
Louisiana (USA)	6	7	6	6	6	-----
Maryland - 1 (USA)	10	8	8	7	4	-----
Maryland - 2 (USA)	-----	-----	-----	-----	-----	-----
Maryland - 3 (USA)	10	10	10	5	5	-----
Maryland - 4 (USA)	-----	-----	-----	-----	-----	-----
Maryland - 5 (USA)	10	8	9	8	8	3
Maryland - 6 (USA)	5	7	7	7	7	-----
Mississippi (USA)	9	8	8	6	7	-----
Missouri (USA)	1	5	5	5	-----	-----
New York (USA)	8	8	8	8	8	-----
North Dakota (USA)	7	8	7	5	10	1
Ohio (USA)	2	8	7	6	6	-----
Oklahoma (USA)	8	-----	-----	8	-----	-----
Pennsylvania (USA)	8	10	10	7	7	2
South Dakota (USA)	8	6	6	2	-----	-----
Tennessee (USA)	4	9	9	8	7	1
Texas (USA)	8	8	8	8	8	-----
Virginia (USA)	10	8	10	8	7	-----
Wyoming (USA)	-----	10	10	10	10	-----
Alberta (CAN)	2	10	8	5	5	-----
British Columbia - 1 (CAN)	10	9	7	8	7	1
British Columbia - 2 (CAN)	7	5	4	3	2	-----
Nova Scotia (CAN)	-----	7	7	5	5	-----
Number of Responses	**28**	**31**	**31**	**32**	**29**	**8**
Average Values	**7.43**	**7.68**	**7.58**	**6.41**	**6.52**	**N / A**

Table 2.6 - Results of the Florida Questionnaire (Section III)

SECTION III - GENERAL AREAS OF CONSTRUCTION OPERATIONS						
Responding Agency	**Constructability Analysis**	**Inspection Operations**	**Quality Control**	**Construct Docs**	**Department Docs**	**Other (# Only)**
Florida - District 2	7	7	7	5	5	-----
Florida - District 2	9	10	9	8	8	1
Florida - District 2	9	9	9	8	8	1
Florida - District 2	-----	8	7	8	7	-----
Florida - District 2	6	7	7	7	6	-----
Florida - District 3	8	9	8	8	7	2
Florida - District 7	8	7	8	9	9	1
Florida - District 7	8	8	8	8	8	-----
Florida - District 7	6	7	5	4	4	-----
Florida - District 7	5	5	5	5	3	-----
Number of Responses	**9**	**10**	**10**	**10**	**10**	**4**
Average Values	**7.33**	**7.70**	**7.30**	**7.00**	**6.50**	**N / A**

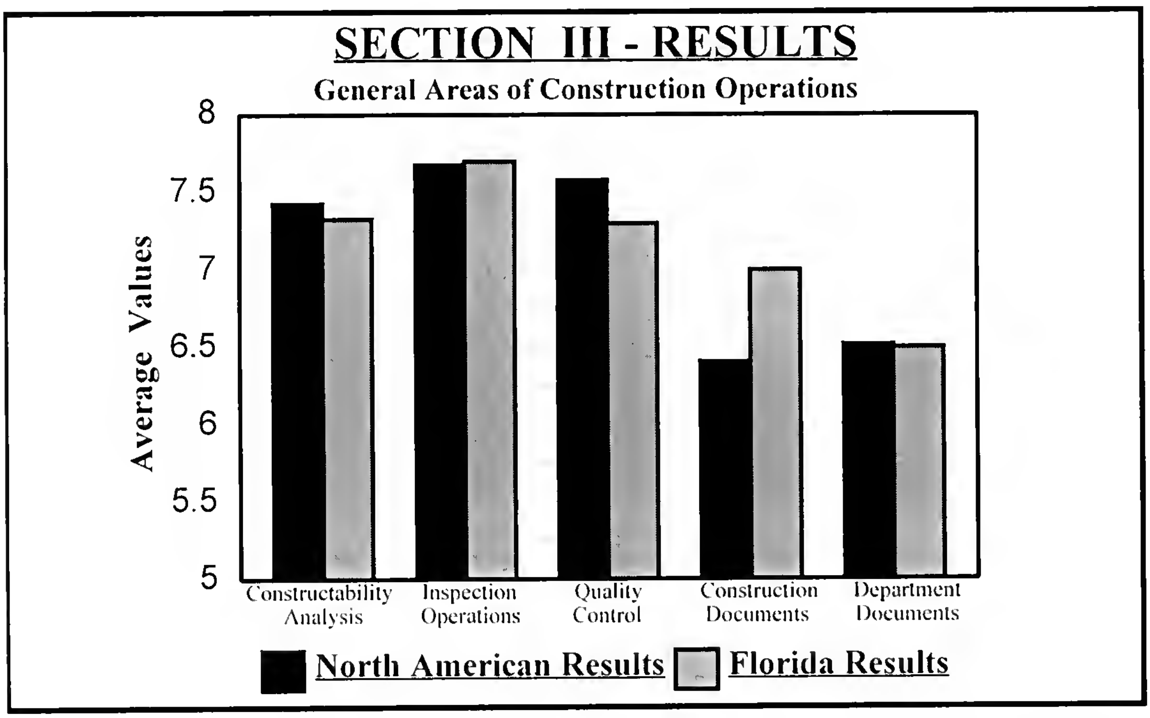


Figure 2.2 - Comparison of Results from North America Versus Florida (Section III)

"Quality Control" were thought to be those general areas of construction operations and administration wherein the loss of experience was deemed to be most critical. With respect to selection of "Other" areas of operations, neither the North American nor the Florida survey yielded any definitive results.

2.1.5.4 Section IV--Knowledge Acquisition and Experience Capture Methodology

Affirmative responses to the existence of the various specified knowledge acquisition and experience capture programs are indicated by an "X" in Table 2.7, for the North American survey, and Table 2.8 for the Florida survey. Referring to Table 2.7, the most popular methods of acquiring knowledge, based on the North American survey, were the "Mentor / Apprentice" approach and the use of retired veteran personnel as "Part-Time Consultants." Results based on the Florida survey (Table 2.8) indicated that, at least among those districts that responded, the only method that appears to be consistently utilized in Florida is the "Mentor / Apprentice" system. Regarding applications of "Other Methods" for acquiring knowledge, one particular technique that was mentioned by a total of five respondents in the North American survey was the organization of training sessions conducted by veteran practitioners. In Florida, on the other hand, no respondent gave any information on any techniques, other than those specifically called out in the questionnaire.

With respect to dissemination of the captured construction knowledge and experience throughout the structure of the organization, the overwhelming method of choice in both surveys among those who chose to comment was the utilization of written construction and inspection manuals. The Florida respondents, specifically those from District 2, commented

Table 2.7 - Results of the North American Questionnaire (Section IV)

SECTION IV - KNOWLEDGE ACQUISITION & EXPERIENCE CAPTURE METHODOLOGY							
Responding Agency	**1 on 1 Interview**	**Round Table**	**Depart Report**	**Mentor / Apprentice**	**Post Construct Conference**	**Part-Time Consultant**	**Other Methods**
Alaska (USA)	X			X		X	
Alabama (USA)							
Arkansas (USA)							
California (USA)	X		X	X		X	X
Colorado (USA)					X	X	X
Connecticut (USA)					X	X	
Georgia (USA)							
Idaho (USA)					X	X	
Illinois (USA)				X	X	X	
Kansas (USA)				X	X	X	X
Kentucky (USA)							X
Maryland - 1 (USA)							
Maryland - 2 (USA)				X		X	X
Maryland - 3 (USA)							
Maryland - 4 (USA)				X			
Maryland - 5 (USA)							
Maryland - 6 (USA)	X	X	X	X	X	X	X
Mississippi (USA)					X		X
Missouri (USA)							
New York (USA)				X			
North Dakota (USA)							X
Ohio (USA)	X			X	X	X	X
Oklahoma (USA)							
Pennsylvania (USA)							
South Dakota (USA)							
Tennessee (USA)				X		X	
Texas (USA)							
Virginia (USA)				X		X	
Wyoming (USA)						X	
Alberta (CAN)	X			X		X	
British Columbia - 1 (CAN)							
British Columbia - 2 (CAN)	X			X	X	X	
Nova Scotia (CAN)							
Number of Responses	**6**	**1**	**2**	**13**	**9**	**15**	**9**

Table 2.8 - Results of the Florida Questionnaire (Section IV)

SECTION IV - KNOWLEDGE ACQUISITION & EXPERIENCE CAPTURE METHODOLOGY							
Responding Agency	**1 on 1 Interview**	**Round Table**	**Depart Report**	**Mentor / Apprentice**	**Post Construct Conference**	**Part-Time Consultant**	**Other Methods**
Florida - District 2		X		X			
Florida - District 2							
Florida - District 2				X			
Florida - District 2				X			
Florida - District 2							
Florida - District 3				X	X		
Florida - District 7				X			
Florida - District 7							
Florida - District 7							
Florida - District 7							
Number of Responses	**0**	**1**	**0**	**5**	**1**	**0**	**0**

on the existence of two particular in-house documents, one is a manual entitled Tricks of the Trade [Jacksonville, 1992], and the other is a collection of inspection checklists which are still presently under development. These documents along with several other FDOT publications will be discussed in detail in Chapter 4 of this dissertation. In the North American survey, there were a total of eight respondents who indicated that their organization had developed some sort of procedural manual for highway construction operations. An example of one such publication received through the questionnaire process is a pocket-sized State of California Department of Transportation manual entitled Highway Construction Checklist [State of California, 1985]. Appendix C includes selected excerpts from this booklet, specifically, the cover, the Foreword, the Table of Contents, and the complete section on Concrete Structures. Although this document is somewhat dated, it does represent a comprehensive attempt by this agency at capturing the highway construction knowledge and experience of its veteran practitioners.

2.1.6 Selected Comments from the KA & EC Questionnaire

Although the survey was rather complex and time consuming, many who participated did take the time to give their final comments on the subject of knowledge acquisition and experience capture as it related to their organization. The loss of valuable expertise through the departure of veteran personnel clearly was of concern to a vast majority of the respondents. Two comments, in particular, have been reproduced herein as an illustration of how significant the problem is and how many perceive their agencies as highly deficient with respect to the implementation of any type of methodology for the capture of the construction knowledge and expertise possessed by veteran practitioners within their organization.

The Chief of the Construction Division for the Louisiana Department of Transportation and Development commented as follows:

> I'm retiring with 33+ years of experience. Most of this has been in structures, including all kinds of bridges and foundation experience. When I leave, there will not be one person in the Department that can approach my experience. This state has done nothing, has no plans to do anything, and probably never will address this matter.

A Resident Engineer in the FDOT made the following statement regarding the level of importance he felt was given to this subject by his department:

> The FDOT does not use any of these knowledge acquisition and experience capture] methods in the construction offices. They give them (departing veteran employees) a hand shake, and say "Good Luck."

Another set of interesting comments that were made on several Florida questionnaires had to do with the use of private construction engineering and inspection firms known as CEIs. These CEI consultants are utilized for contract administration and

inspection operations on substantial amounts of the highway construction work that is currently being contracted out by the FDOT. Typically CEI firms in the state of Florida regularly hire retiring FDOT personnel and resell their services back to the Department. Although these individuals are no longer technically employed by the FDOT, the Department still benefits from their knowledge and expertise. Whereas some in the FDOT question certain aspects of this practice, as evidenced by the following two comments, all agree that today, the use of CEIs is an integral and established part of highway construction operations within the state of Florida.

An FDOT Construction Training Engineer has this to say about CEI firms:

> A lot of our employees retire with 30+ years of experience and go to work for a consultant (CEI) that has a contract with us. Thus we never loose their experience or knowledge, we just pay them more for it.

A Project Manager with the FDOT made similar comments with respect to CEI firms and departing veteran practitioners:

> This experience is not truly lost because most (90%) of the departing employees immediately go to work for CEI consultants who work directly with the Department. The Department, looses the opportunity to direct these personnel in ways which would better benefit the people of Florida.

2.1.7 Summary

As previously noted in the research objectives, one of the fundamental purposes of the KA & EC questionnaire was the identification and prioritization of the general categories of highway construction work and operations wherein the loss of experience was felt to be most critical. The area distinguished as most acute would then become the focus of continued research and development. Analysis of Section II and Section III of the KA & EC

questionnaire indicated that in both the North American and Florida surveys, basically the same general categories of work and areas of operations were rated as those most affected by the loss of experience . Based on these rather conclusive results, it was determined that the research effort from this point forward would be concentrated on inspection operations associated with the construction of new bridges. Although other categories of work and areas of operations rated at near similar levels, it was felt that this particular selection offered the best opportunity for the development of a prototype system that would appeal to the widest audience within the FDOT.

Another observation that can be drawn from a final review of the KA & EC questionnaire is the apparent lack of any kind of functional implementation of knowledge based programs among the various responding transportation agencies. The survey was distributed specifically to those personnel who were in positions of supervising the construction operations within their agencies. The questionnaire purposely made no direct references to the term "expert systems" (see Chapter 3 for a discussion of this technology), in order to ascertain the practical level of use of these types of systems without unduly prompting such responses. It is very interesting to note that from a total 44 completed questionnaires, only two respondents made any mention at all of expert systems as a method by which their department was attempting to capture and disseminate construction knowledge and experience. One of the two, the New York State Department of Transportation, actually commented on the fact that after participating in a research project for the development of an asphalt paving expert system in the early 1990s [Williams et al., 1990], the department reviewed the findings and decided not to pursue such an approach. The other agency, however, the Alberta Department of Transportation and Utilities, did

report a significant commitment to the development of expert systems. Since 1990, this organization has initiated the development of 16 expert systems, of which 11 have been fully implemented. However, by their own admission, these systems require an inordinate dedication of departmental resources and time, which has caused somewhat of a reduction in the popularity of continuing these types of efforts in the future.

2.2 TRB Information on Current Practices

2.2.1 TRB Synthesis on Knowledge Based Expert Systems

During the literature review process, details of which are presented in Chapter 3, a Transportation Research Board (TRB) report entitled "Knowledge Based Expert Systems in Transportation, A Synthesis of Highway Practice" was uncovered [Cohn and Harris, 1992]. As part of this synthesis, a survey was conducted in an attempt to ascertain the current level of development and implementation of knowledge based expert systems among this country's SHAs. Table 2.9 represents the outcome of this survey. It should be noted the numbers listed under the column heading "Stage of Development" indicate that the responding state has been involved with one or more knowledge based expert systems (KBES) at the designated stage of development as described in the table's legend (1 through 6). The numerical sequence, however, does not necessarily match the activity areas listed in the last column entitled "KBES Activity Area." Examination of Table 2.9 suggests that the transportation industry appears to be somewhat more involved in the development of KBES technology than was evidenced by responses to this dissertation's KA & EC questionnaire.

Table 2.9 - Level of KBES Activity Among the SHAs of the United States

Responding State	Stage of Development	KBES Activity Areas
California	1, 2, 3, 4, 5	Hazardous materials; Traffic incident management; Water quality; Concrete products; KBES priority
Connecticut	3, 5	Pavement rating; Impact attenuator design
Illinois	1, 3	KBES priority Emergency response
Kansas	1, 3	Concrete construction; Concrete pavements
Maryland	3	Freeway incident management
Minnesota	4	Processing truck permits
New Jersey	3, 5	Noise barrier design; Infrastructure risk management
New York	3, 4, 5, 6	Snow problem location; Asphalt paving inspection; Pavement marking; Concrete analysis; Infrastructure risk management; Steel bridge inspection
Oklahoma	1	KBES state of the art
Oregon	3	Truck weight analysis
Pennsylvania	3, 5	Automated bridge design / drafting; Structural failure analysis
South Dakota	3	Processing truck permits
Texas	2, 3, 4	Bridge rail retrofit; Constructability enhancement; Pavement analysis
Utah	3	Construction evaluation
Virginia	5	Traffic control in work zones; Disposition of old bridges
LEGEND	KBES = Knowledge Based Expert Systems 1= Conceptual; 2 = Prototype in development; 3 = Prototype under testing; 4 = Detailed KBES in development 5 = KBES in use; 6 = Project terminated	

Source: [Cohn and Harris 1992]

2.2.2 Survey of the TRB Construction Management Committee

As a follow up to the KA & EC survey and influenced by the TRB synthesis on knowledge based expert systems in transportation, it was decided that a subsequent letter of inquiry would be transmitted to a slightly different focus group of industry practitioners, ones who may have additional information with respect to the more theoretical aspects of capturing highway construction knowledge and experience. To this end, a directory of names was compiled from a current list of members of the Construction Management Committee (A2F05) of the TRB. It was felt that these people represented a more research oriented cross section of the highway construction industry. However, in keeping with the objectives of surveying industry personnel specifically, all members of the Committee who were academicians were eliminated from the list. This left a final total of 18 people from a variety of different transportation related organizations. The breakdown of their affiliations is as follows:

A) One person was from the Norway Public Roads Administration.

B) One member was employed by the TRB National Research Council.

C) One was from the Federal Highway Administration.

D) Six of the 18 worked for various SHAs.

E) One was from the L.A. County Transportation Authority.

F) Eight were from various private contracting and engineering firms.

Each of these 18 individuals was then sent a letter of inquiry, a generic copy of which appears in Appendix D along with the associated distribution list. Two representative examples of the responses received, one being from Parsons Brinckerhoff Construction Services, Inc., and the other from Martin L Cawley & Associates, is included as Appendix

E. In all, nine out of the original 18 contacted members responded. As was the case with the original KA & EC survey, expert systems were not specifically mentioned in order to gauge their level of acceptance among this particular group. Although many of the comments received were very interesting and well thought out, not a single respondent referred to the existence of any type of expert systems as a method by which their organization was attempting to capture construction knowledge and experience.

Another point of agreement between the information gathered through this letter of inquiry, and that gleaned from the responses to the KA & EC questionnaire, was the popularity of documenting construction knowledge through the development of construction manuals. As an example of another such construction manual, Appendix F contains copies of the cover, the Foreword, the Table of Contents, and subsections I to V of Section 550 (Structural Deck Inspection Guide), as reproduced from the New York State Department of Transportation's Construction Supervision Manual [New York, 1984]. Although this publication was received as a result of contact with the New York Department of Transportation via the letter of inquiry, it should be noted that this manual was also mentioned in the comments from the New York respondent to the KA & EC questionnaire.

2.3 Current Practices Within U.S. Army Corps of Engineers

2.3.1 General Comments

Although this research effort was focused on highway construction, communication was established with several large construction organizations that were not specifically affiliated with the transportation industry. From these preliminary investigations, the U.S.

Army Corps of Engineers clearly set itself apart from other construction entities by the level of commitment this organization has placed on acquiring and capturing the construction knowledge and expertise of its personnel.

2.3.2 Jacksonville District Corps of Engineers

Initial contact with the Corps was made through their district office in Jacksonville, Florida. One outcome of preliminary interviews conducted with members of this office was the reference to another sample of a construction inspection manual. Appendix G contains the cover, the Foreword, the Table of Contents, and Sections 2G-01 (General) and 2G-02 (General Requirements) from Chapter 2G (Pile Construction), reproduced from Volume 2 of a four part handbook entitled Construction Inspector's Guide [U.S. Army Corps of Engineers, 1986]. As was the case with the manuals obtained from the various SHAs, refer to Appendix C and Appendix F for examples, this document also was written from the position of managing construction work from the perspective of the government agency charged with administering the contract.

Another interesting methodology initiated by the Corps in an effort to capture construction knowledge and experience, is their program of developing "Lessons Learned Reports" for the analysis of special problems associated with projects that were constructed under their jurisdiction. An example of such a report appears in Appendix H of this dissertation. This Lessons Learned Report, generated in the Jacksonville District Corps of Engineers office, was based on a recently completed project known as the Cerrillos Dam project. What makes this report especially useful, is the Corps' insistence on relating the lessons learned from the Cerrillos Dam project to a similar upcoming project, known as the

Portuguese Dam. Not only does this report identify problematic areas encountered during design, construction, and ongoing operations of a completed project, it also institutes a procedural method for application of past lessons learned to a specific upcoming project. What this program represents is a systematic approach, on the part of the Corps, attempting to capture knowledge and expertise by documenting the experiences of their personnel with respect to a specific construction project. Furthermore the establishment of a process which requires that the lessons learned from the Cerrillos Dam project be implemented on the upcoming Portuguese Dam project, is a very sound method that should help to mitigate the repetitive occurrence of past problems on future projects.

2.3.3 U.S. Army Construction Engineering Research Laboratories

2.3.3.1 General comments

The examples, as per Appendices G and H, of some of the techniques within the Corps for capturing knowledge and experience which have been presented up to this point are certainly worthwhile endeavors which document organizational construction expertise. The key word here is "document" as it refers to the traditional paper-based methods of storage and distribution of information. With the advent of the personal computer, and the proliferation of electronically based information management systems, one would assume that somewhere within the Corps there must exist more computerized approaches for the capture and dissemination of construction knowledge and experience.

The U.S. Army Corps of Engineers is the largest public engineering organization in the world. Falling under their jurisdiction, is the administration of the construction programs for both the Army and the Air Force, at an annual budget of over five billion dollars, not to

mention their duties associated with managing a myriad of domestic engineering concerns, such as keeping this nation's waterways navigable [USACERL, 1993a]. In 1969, the Corps established the U.S. Army Construction Engineering Research Laboratories (USACERL) in an effort to develop new construction innovations that would serve to enhance the Corps' future capabilities of managing their growing network of construction and maintenance related operations. Over the years, USACERL has become one of this country's premier construction research and development institutions, and as such, it seemed to be a likely place to continue the search for more state-of-the-art systems that may possibly take advantage of today's emerging technologies.

2.3.3.2 Developmental knowledge based expert systems

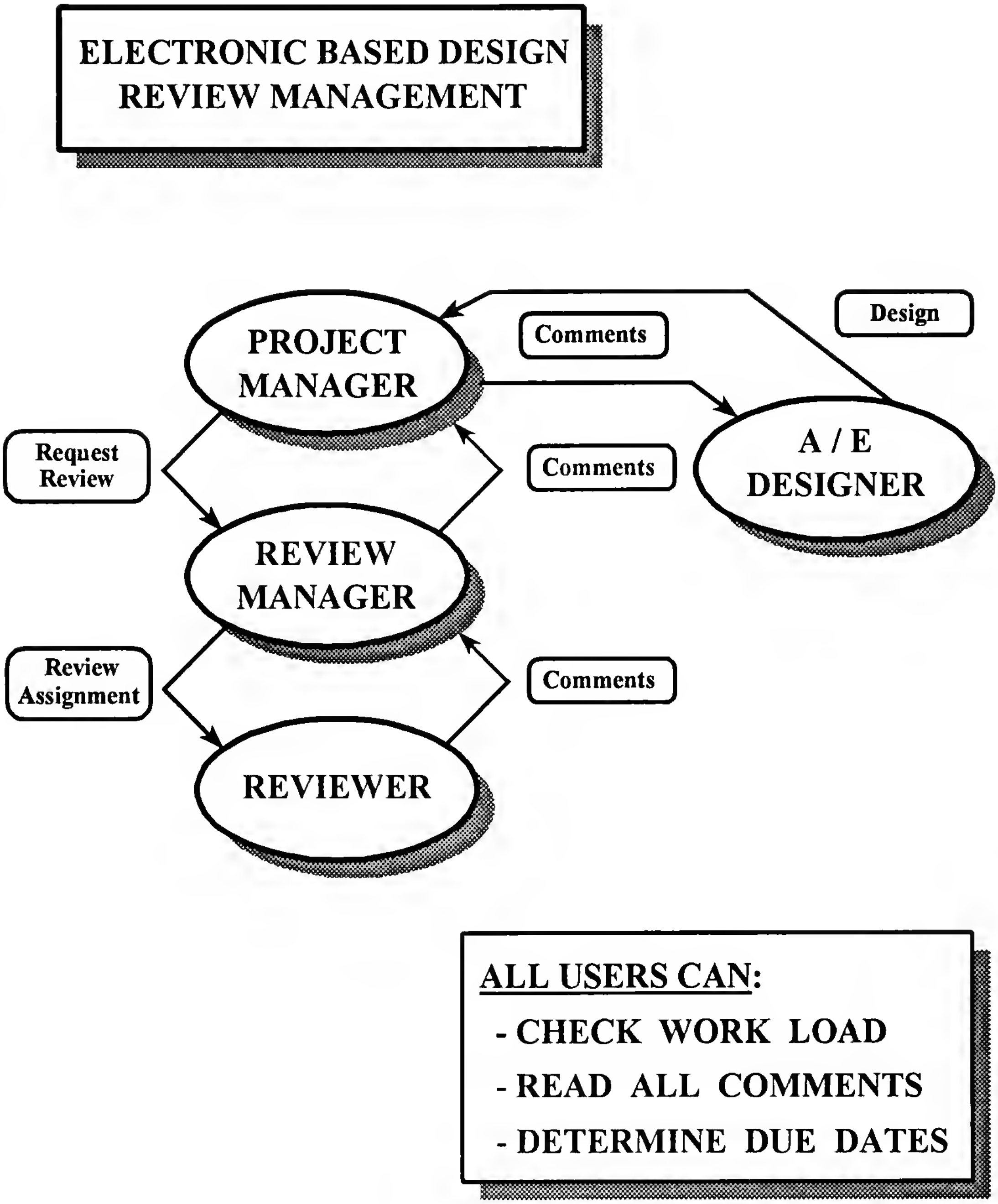
Preliminary discussions were initiated with the USACERL headquarters in Champaign, Illinois. Results of these conversations led to the discovery of several knowledge based expert systems (KBES) that were currently under development dealing with a variety of construction related topics. Fact Sheets, provided by USACERL, describing two such systems have been included in Appendix I. The first example is that of a KBES designed to "assist Corps management and technical personnel in using the Design/Build method of construction contracting" [USACERL, 1993b]. The second Fact sheet also describes an expert system called Claims Guidance System (CGS). According to the documentation, CGS analyzes the "relevant information regarding a particular claim" provided to the system by the user, and based on current legal precedence, generates a set of expert recommendations [USACERL, 1993c].

2.3.3.3 ARMS and the BCOE Advisor system

Although expert systems are one method by which USACERL is attempting to electronically capture construction expertise, the inherent narrow focus, coupled with the arduous task of creating KBES rule sets has led to research into alternate approaches. One of the most interesting and comprehensive efforts underway at USACERL is their work on the programs known as ARMS (Automated Review Management System), and the BCOE (Biddability, Constructability, Operability, and Environmental compliance) Advisor system, which is a developmental extension of ARMS.

In an initial step towards automating the design review process, the computer experts at USACERL began developing ARMS. This program is basically an extensive database of project review comments maintained by the Technical Center of Expertise (TCX) at the Sacramento District, Corps of Engineers office in California. The fundamental purpose of ARMS is to provide all members of a project team a "management tool for the collection, resolution, and storage of comments generated during the design/construction life of a project." Figure 2.3 presents a schematic flowchart which illustrates the method by which ARMS manages the comments which arise as a result of the design review process. Quoting again from the ARMS manual, "This program is tailored to replace the current system of receiving and resolving hand written design comments" [U.S. Army Corps of Engineers, 1992].

As a part of the overall design review process, that which ARMS was created to help manage, the U.S. Army Corps of Engineers requires what is known as a BCOE (Biddability, Constructability, Operability, and Environmental compliance) review on all of their projects. The concept is to involve construction personnel in this BCOE review in order to identify the



Source: [Roessler et al., 1993]

Figure 2.3 - Schematic Flowchart of ARMS Operations

construction related problems. Upon recognition of these problems, the designer is then informed, and thus can modify the design so as to avoid costly construction contract modifications and minimize the cost of building operations and maintenance. As a computerized extension of ARMS, in the realm of BCOE reviews, USACERL initiated work on a program called the BCOE Advisor. It is interesting to note that the developers of this system originally experimented with a rule based KBES upon which to build their BCOE Advisor prototype, however, this approach soon was found to be inappropriate for the unique nature of the construction projects being reviewed. Instead, it was decided that the BCOE Advisor would be produced on rBASE, a commercially available relational database software package marketed by the Microrim Corporation. According to the BCOE Advisor programmers, rBASE was selected because at the time it was the only PC platform database system that supported the American National Standard Institute's (ANSI) Standard Query Language (SQL) [Roessler et al., 1993]. Storing the BCOE Advisor data in SQL would then make it possible to import and export comments to and from ARMS directly in a standardized format.

What the developers of the BCOE Advisor system attempted to do was to augment the BCOE process by creating a database system that could 1) conceptually access past design review comments from ARMS, 2) modify these comments with respect to the current project being reviewed, and 3) store these new modified comments for future use. Figure 2.4 illustrates the basic operations of the BCOE Advisor system and its interface capabilities with ARMS. Fundamentally, as Roessler et al. [1993] suggest, what this established was a system that provided a "lessons learned capturing program to assist in the generation of high quality, ARMS compatible, design review comments."

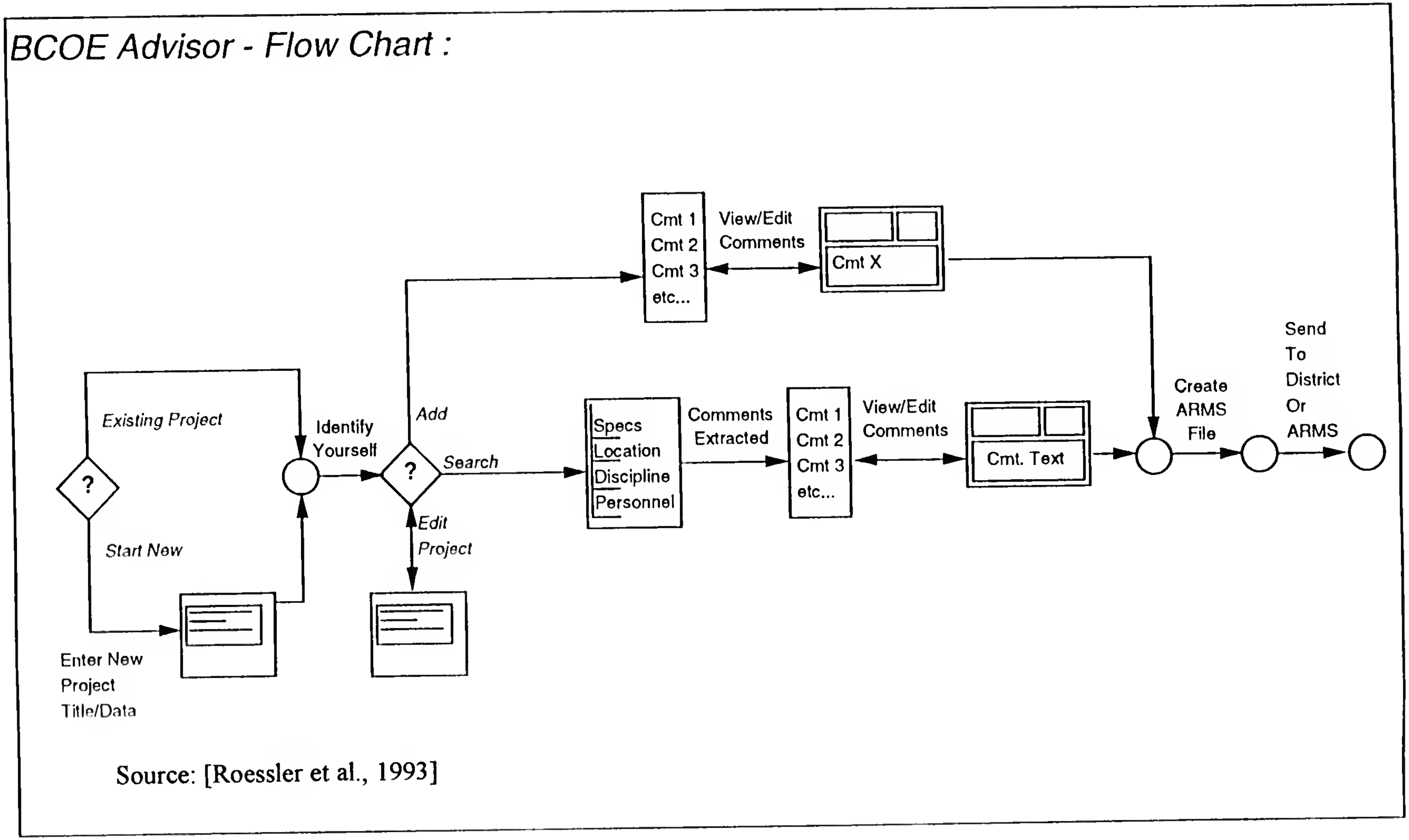


Figure 2.4 - Schematic Flowchart of BCOE Advisor Operations

2.4 Summary of the Survey of Current Practices

2.4.1 The General Category of Work for Further Concentration

One of the fundamental purposes of surveying current practices within the highway construction industry was to distinguish that area of highway construction work in which those in the industry felt that the effects associated with the loss of experience due to the departure of veteran personnel was most acute. From the responses to Section II of the KA & EC questionnaire as presented in this chapter, the general category of "New Bridge Construction" clearly established itself as the highest rated category in level of importance given to experience based issues.

The survey also looked at those operative and administrative duties that typical construction staff members are most regularly involved in. Again from the results of the KA & EC questionnaire, the three areas from Section III that were identified as being most affected by the loss of experience were "Constructability Analysis," "Inspection Operations," and "Quality Control." The area of "Constructability Analysis," although obviously related to construction operations, is also heavily involved in the design aspects of highway work. As such, and keeping in mind that the original scope of the study was specifically on that of construction operations, it was decided that this area would not be singled out for further concentration. With respect to construction operations, one of the primary functions of "Quality Control" is accomplished by ensuring that the finished product has been built in accordances with the plans and specifications, as well as all other applicable construction related practices and requirements. Therefore, much of the burden of monitoring the field quality and compliance of the finished product falls squarely on the shoulders of those people who are in charge of the "Inspection Operations."

Taking into account the totality of the KA & EC questionnaire responses, coupled with the original goals as set forth in the research objectives, it was decided that the subsequent knowledge acquisition efforts were going to be limited to "New Bridge Construction" with a focused attention on "Inspection Operations." Not only did the survey bear out these results, but conversation with many FDOT personnel indicated that this concentrated effort would reach the widest audience within the Department. And as has been noted, since the end-user in this case was to be the FDOT, it only served to strengthen this decision.

2.4.2 Knowledge Acquisition and Experience Capture Methods

2.4.2.1 Inspection and operational manuals

By far, the most popular technique of capturing construction expertise was the utilization of written construction inspection and operational manuals. Although these types of manuals were found to exist in most of the construction organizations contacted, many of the comments received regarding these documents acknowledged their limited effectiveness. It is not that these manuals do not contain significant amounts of quality information, rather it is more a function of the cumbersome way in which this information is presented.

2.4.2.2 U.S. Army Corps of Engineers Lessons Learned reports

The U.S. Army Corps of Engineers Lessons Learned reporting program was a method of experience capture that appeared to be very productive. The concept of documenting the problematic areas of a particular job creates a more systematic approach to knowledge acquisition. The fact that project personnel are able to discuss relatively recent occurrences of a specific nature, yield comments that are more focused and ultimately more

useful. This technique was deemed to be one which demonstrated promise for implementation with respect to this dissertation's efforts in regards to the capture of highway construction knowledge and experience.

2.4.2.3 Current computerized developmental efforts

With respect to cutting-edge computer based technologies, the field of expert systems seems to be the one that has attracted the most attention of late. Although there are a number of transportation related KBES programs currently under development, as evidenced by Table 2.9, results of the KA & EC questionnaire, along with the subsequent contacts made with other organizations, both in and out of the highway construction industry, indicate that the functional utilization of expert systems by those personnel who are directly associated with day-to-day construction operations is very limited or nonexistent. Wentworth [1993] suggests that an explanation for this lack of practical acceptance by the industry may be due to the fact that in his opinion, highway applications of expert systems "appear to be more developer-driven than user-demanded."

Another interesting computer application uncovered at the U.S. Army Construction Engineering Research Laboratories (USACERL) was their conceptual database for the management of comments generated through the BCOE (Biddability, Constructability, Operability and Environmental compliance) portion of the design review process. The program, which is called the BCOE Advisor is a very innovative method of storage and retrieval of text based comments. Although not specifically related to the highway construction industry, the idea of relating comments of similar subject matter and providing conceptual access to this information certainly is an approach worth investigating.

One class of information software that has yet to be discussed but which shows great promise for managing construction related text and graphics is the technology known as hypertext. Williams [1991], in an article describing a hypertext asphalt paving system that was developed in conjunction with the New York State Department of Transportation (NYSDOT), defines hypertext as a “database system of text and graphics that allows a reader to jump from idea to idea depending on one’s interest.” This article in particular was chosen to quote because Williams is the same person who had participated in the previously mentioned development of the asphalt paving expert system [Williams et al., 1990] that was subsequently abandoned by the NYSDOT. According to the NYSDOT respondent to the KA & EC questionnaire, after departmental review of the hypertext system as compared to the expert system, the hypertext system was deemed to be more suited to their needs and is currently being successfully utilized.

Another example of a hypertext application found within the transportation industry is a program called the Highway Constructability Improvement System (HCIS), which was developed for the Washington State Department of Transportation (WSDOT). In an article written for the Transportation Research Board, HCIS is described as database of information extracted from five years worth of WSDOT change orders. The WSDOT felt that by using HCIS, engineers at their design office could access knowledge from past construction related experiences that resulted in change orders, and hopefully avoid similar errors in preparing future design plans and specifications [Lee et al., 1991].

2.5 Final Comments on the Survey of Current Practices

In general, based on the survey of current practices, there did not appear to be any comprehensive highway construction knowledge acquisition and experience capture programs that had gained any significant levels of acceptance among those practitioners who are intimately involved in the day-to-day operations of building this country's highway systems. It was felt that for a knowledge acquisition and experience capture program to be successful in an organization such as the FDOT, the information delivery system must cater to the needs of the end user. Although some promising developments in the area of information management were uncovered, further review into the current literature associated with this field of study is required, and as such, will be pursued in detail in Chapter 3 of this dissertation.

CHAPTER 3
REVIEW OF PUBLISHED LITERATURE

3.1 Introduction

Up to this point in the research endeavor, significant effort had been focused on the identification of the methods by which different agencies within the highway construction industry were attempting to acquire knowledge and experience, and disseminate this captured knowledge to other members of the organization. Although no one singular system that fully addressed all the issues of capturing construction knowledge and experience as set forth in this dissertation's research objectives had been uncovered, in particular, the three information management technologies of expert systems, hypertext, and database management systems had emerged as likely candidates for utilization in one form or another as potential tools for possible realization of the stated objectives. It was apparent that as stand alone entities, none of these three branches of information management could be considered as fully responsive to the needs of the proposed system. However, it was felt that by integrating certain aspects of each type of computer software, a prototype computerized system could be developed that would create an intuitive, user-friendly environment for the capture and dissemination of highway construction knowledge and experience.

With this in mind and concurrent with the survey of current practices, as detailed in Chapter 2, an extensive literature survey was undertaken utilizing the University of Florida's

on-line searching capabilities of the Library User Information Services (LUIS). Additionally, a computer database search was conducted through the Southern Technology Applications Center (STAC), which like the university, is also located in Gainesville, Florida. At STAC, two of the most comprehensive, commercially available engineering index services, DIALOG (File 63--TRIS) and COMPENDEX, were queried. These searches were focused on the distinct fields of study relating to expert systems, hypertext, and database management systems, in order to gain a better understanding of the various capabilities of each of these information management techniques. With a firm grasp of the underlying functionality associated with these technologies, intelligent decisions could then be made with respect to the level and strategies of integration that would be pursued. The results of this review process, along with conclusions for the proposed system integration, will be presented in the following sections of this chapter.

3.2 Knowledge Based Expert Systems

3.2.1 General Comments

Although the standard knowledge based expert systems (KBES) that are currently being developed in the highway construction industry have shown themselves to be inherently narrowly focused and typically not well received by industry practitioners, it was felt that there may be certain properties associated with expert systems that might turn out to be very useful. In order to determine what aspects of the KBES approach may be worthwhile in the context of this research effort, the concept of what an expert system is and exactly what it does will be explored next.

3.2.2 Historical Background

Knowledge based expert systems (KBES), as they exist today, are a direct outgrowth of the artificial intelligence techniques that began to develop after World War II. In 1956, a group of scientists from such fields as electrical engineering, mathematics, neurology and, psychology, got together at Dartmouth College in New Hampshire to discuss the possibilities of utilizing the computer as a means of simulating various aspects of human intelligence. The proposed intent of the Dartmouth Conference was to explore the conceptual supposition "that every aspect of learning or any other feature of intelligence can in principle be so precisely described, that a machine can be made to simulate it." They termed this new technology Artificial Intelligence (AI) [Rose, 1984].

One result of the Dartmouth Conference was the establishment of future aspirations for the AI field. It was forecasted that by 1970, a computer would be able to do the following:

1) be a grandmaster at chess;
2) discover significant new mathematical theorems;
3) understand spoken languages, and provide language translations; and
4) compose music of classical quality.

By the mid 1960s, it had become painfully apparent that these lofty goals of true artificial intelligence set by the Dartmouth Conference were not going to be met, and in hindsight they were very unrealistic. The AI community regrouped and began to consider more modest goals for the intelligent machine. They agreed that knowledge was the essential ingredient of intelligence. They also realized that the computer, despite its sizeable capacity for data storage, was not able to store and process the incredible amount of information that would

be necessary to simulate actual cognitive human intelligence. They therefore decided that for the time being, they would focus their research and adopt the following strategies:

1) be more modest;
2) be more focused; and
3) direct system development towards a narrow sector (domain) of expertise, rather than attempt to simulate general overall human intelligence.

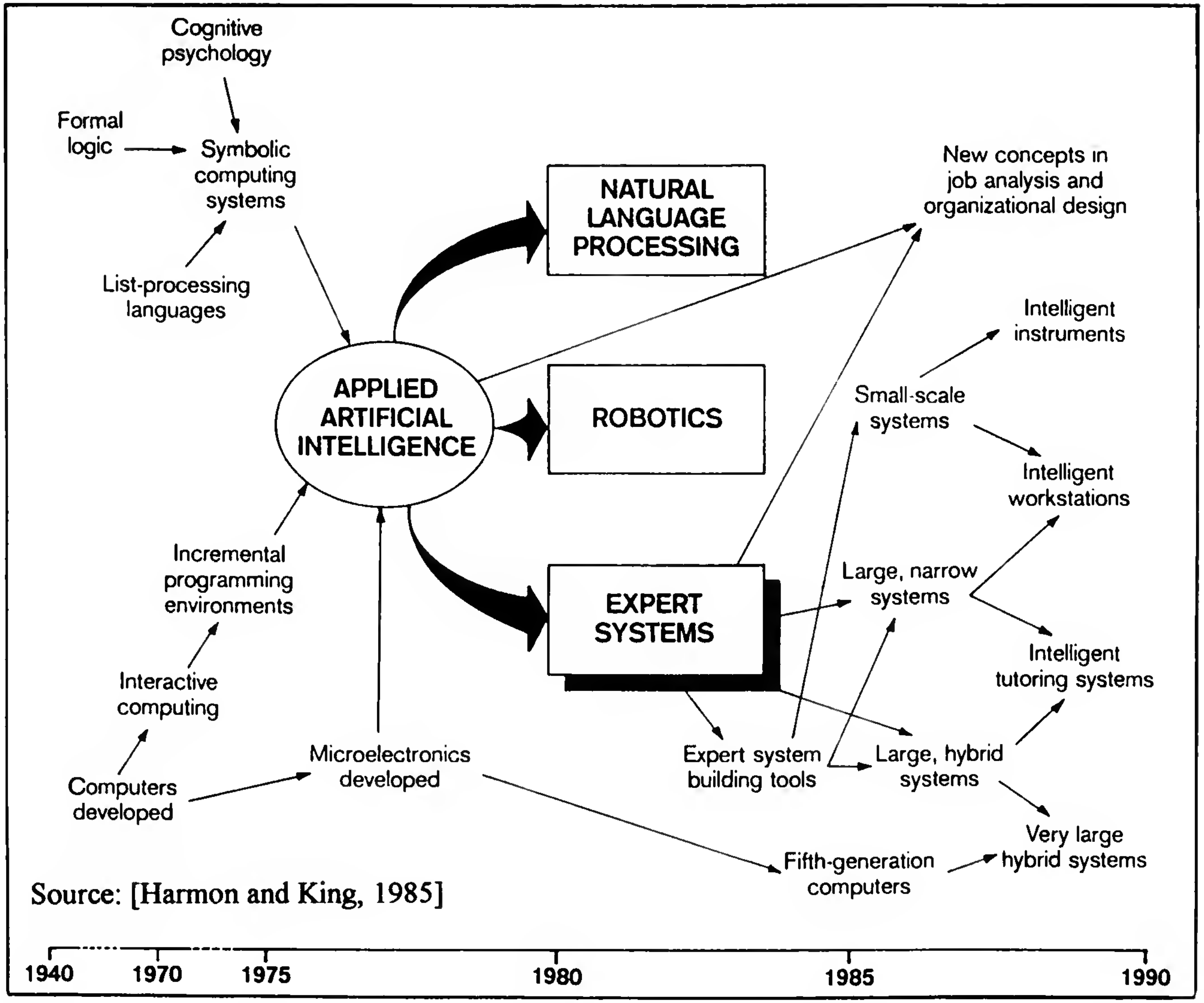
The name given to this new subfield of AI was Expert Systems or Knowledge Based Expert Systems (KBES) [Ignizio,1989]. Figure 3.1 illustrates the history of expert systems as they evolved from artificial intelligence [Harmon and King, 1985].

3.2.3 Generalized Overview of Knowledge Based Expert Systems

3.2.3.1 Definition

A KBES is a sophisticated computer program that manipulates knowledge of a specific domain in such a way as to solve complex problems that would otherwise require extensive human expertise [Waterman, 1986; Rolston, 1988]. Probably one of the most frequently quoted and comprehensive definitions of what constitutes a KBES can be attributed to Professor Edward Feigenbaum of Stanford University, a leading authority in expert systems research. Feigenbaum defines an expert system as follows [Harmon and King, 1985]:

> An expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Knowledge necessary to perform at such a level, plus the inference procedures used, can be thought of as a model of the expertise of the best practitioners of the field.



Source: [Harmon and King, 1985]

Figure 3.1 - History of the Evolution of Expert Systems from Artificial Intelligence

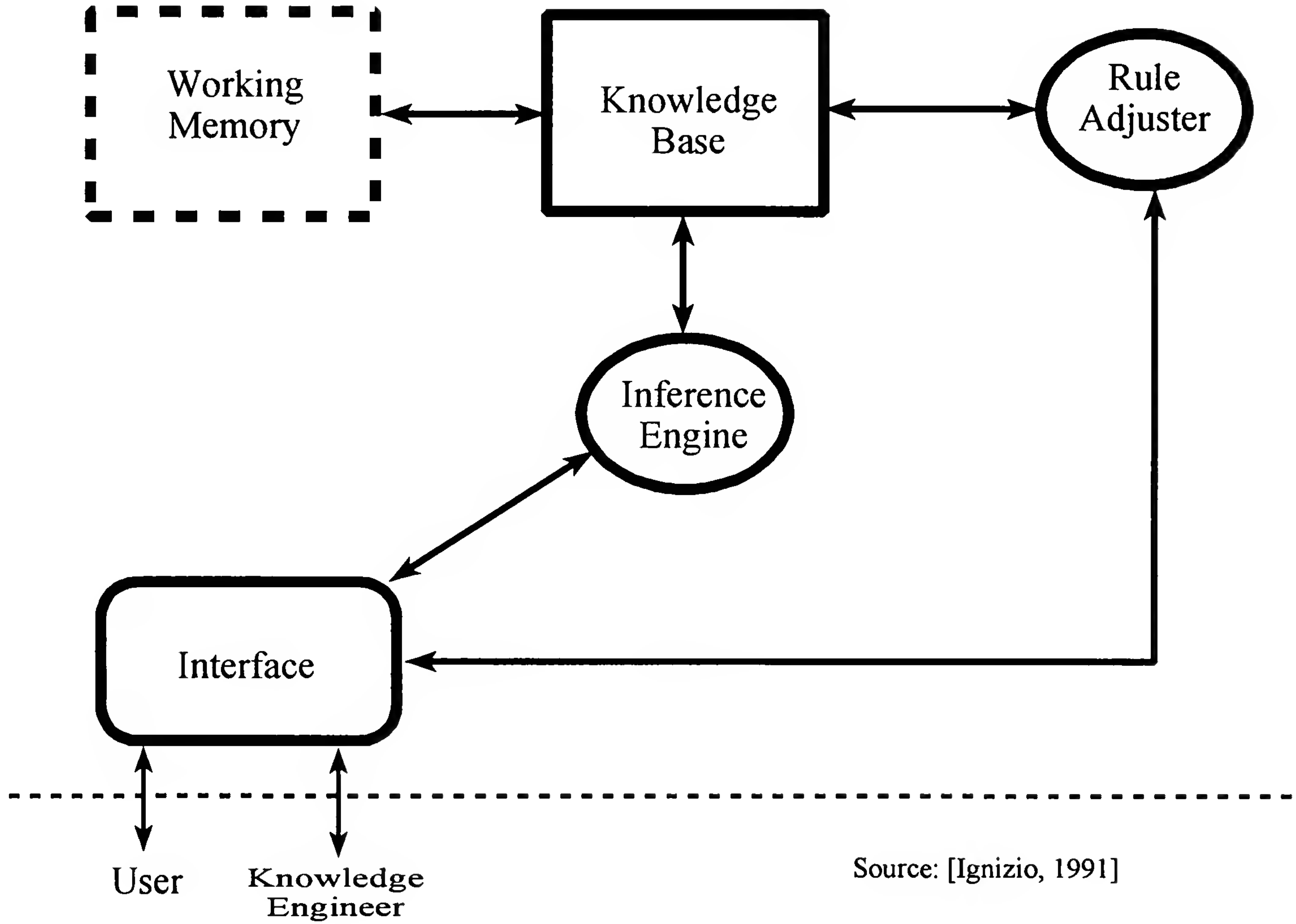
> The knowledge of an expert system consists of facts and heuristics. The 'facts' constitute a body of information that is widely shared, publicly available, and generally agreed upon by the experts in the field. The 'heuristics' are mostly private, little-discussed rules of good judgement (rules of plausible reasoning, rules of good guessing) that characterize expert-level decision making in the field. The performance level of an expert system is primarily a function of the size and the quality of the knowledge base it possesses [p. 5].

3.2.3.2 Functional components of a generic KBES

3.2.3.2.1 General comments. The typical architecture of a generic KBES is illustrated in Figure 3.2 [Ignizio, 1991]. Based on this figure, a brief discussion of each component and its functional relationship to the overall system will be presented next.

3.2.3.2.2 The human/computer interface. The dotted horizontal line represents the cut off point between human users and the computer operations. Below the line there is the "User" who is the non-expert person utilizing the system. The "Knowledge Engineer" is the person who interfaces with the domain expert, defines the expert's knowledge, and models it in such a way so as it can be loaded into the computer. The process by which the "Knowledge Engineer" seeks out and captures this knowledge and expertise is commonly referred to as knowledge acquisition [Parsaye and Chignell, 1988]. Knowledge acquisition has developed into a subspecialty in its own right, and will be discussed in more detail in Chapter 4. Continuing with the human/computer interrelationship, the "Interface" is the system's component that controls all input/output functions that take place between the computer and either the "User" or the "Knowledge Engineer."

3.2.3.2.3 The knowledge base. The "Knowledge Base" is universally recognized as the "heart and soul" of any KBES [Parsaye and Chignell, 1988; Ignizio, 1991]. As earlier stated in Feigenbaum's eloquent description of an expert system, the "Knowledge Base"



Source: [Ignizio, 1991]

Figure 3.2 - Architecture of a Generic Knowledge Based Expert System

stores two types of knowledge (facts and rules). To reiterate, facts are statements whose validity are widely accepted as truth. Facts are obviously significant in assuring the accuracy of the system, but they alone cannot be used for reasoning. By relating facts together with rules however, relationships can be represented, reasoning can then be inferred, and new facts can be derived. Representation of the knowledge in the "Knowledge Base" can be achieved utilizing a variety of methods which include production (IF...THEN...) rules, semantic networks, object-attribute-value (OAV) triplets, and frames [Waterman, 1986; Adeli, 1988; Dym and Levitt, 1991]. Of these knowledge representation schemes, the production rule approach is by far the most widely used and easiest to understand. With this in mind, any future reference to knowledge representation within this generalized overview presentation, will concentrate on the production rule metaphor.

3.2.3.2.4 The working memory. The "Working Memory," which is often referred to as the context component of the KBES, is similar to the "Knowledge Base" in that it also contains facts. However, the difference is that the facts within the "Knowledge Base" are statically imbedded, that is to say that these facts are existing and do not undergo change during system utilization. The "Working Memory" , on the other hand, dynamically stores new facts which are generated by the system itself in one of two ways. "Working Memory" facts are either derived from the cycling of the "Inference Engine," or they are produced as a result of consultations with the "User."

3.2.3.2.5 The inference engine. The "Inference Engine" is the mechanism by which the KBES locates existing knowledge and infers new knowledge from the "Knowledge Base." The "Inference Engine" accomplishes two main objectives:

1) It examines the existing facts and rules within the "Knowledge Base," and when possible it adds new facts to the "Working Memory."

2) It also controls the order in which the inferences are made. The most common inference strategies are forward chaining , backward chaining, or some type of combination of these two approaches.

3.2.3.2.6 Forward chaining. As noted previously, in a rule based KBES, the knowledge is represented by a collection of IF... THEN... production rules. The concept of forward chaining, also known as "bottom up" or "data driven" searching, can best be explained by examining what happens within the generic KBES that has been under discussion. In general terms, initial data is supplied to the KBES through consultation with the "User." This data is then compared to the IF portion of the rules in the "Knowledge Base." When a particular IF part of a rule is deemed to be true, that is to say that the KBES matches supplied data to an IF condition, then the rule "fires," creating a new fact (the THEN portion of the rule) which is immediately added to the "Working Memory." In an iterative process, the rule base is reexamined continuing to utilize the initial supplied data in conjunction with the new inferred facts in an attempt to deduce a solution to the problem at hand. Forward chaining is therefore best suited for situations wherein the KBES is called on to interpret a set of incoming facts, and reach some kind of conclusion based on this incoming data [Maher, 1987].

3.2.3.2.7 Backward chaining. Backward chaining, which is also commonly referred to as "top down" or "goal driven" searching, is a much more difficult strategy to understand, but in simplistic terms, it can be thought of as basically the reverse of forward chaining. Under the backward chaining approach, the KBES compares the desired goal (hypothesis) to the THEN portion of the production rules in an attempt to evaluate whether or not the IF part of the applicable rule or rules can be justified. If successful, the goal is established and the KBES reports its results, otherwise another hypothesis is formed and the "Inference

Engine" repeats the procedure [Bielwaski and Lewand, 1991]. Backward chaining, due to the fact that the inference strategy is goal driven rather than data driven, would therefore tend to be more useful under those conditions where the number of possible solutions is limited.

3.2.3.2.8 The rule adjuster. The final module that will be discussed herein is the "Rule Adjuster." This component is really nothing more than an editor for the rules. In other words, the "Rule Adjuster" is the tool by which the "Knowledge Engineer" enters and modifies the rules of the "Knowledge Base" during the KBES development and subsequent maintenance.

3.3 Hypertext

3.3.1 General Statement

Further research into the standard KBES approach for capturing and disseminating highway construction knowledge and experience revealed, as was preliminarily suspected, that the basic architecture of such a system represented a rather restrictive developmental environment. The effort required to capture the vast amounts of construction related knowledge and expertise possessed by a large organization, such as the FDOT, would be extremely cost prohibitive, and as such not very practical with respect to the stated objectives of this research endeavor. As previously noted in the problem statement contained in Chapter 1, and further confirmed by the results of the KA & EC questionnaire presented in Chapter 2, most of the SHAs in the United States have invested significant dollars and time over the years developing an assortment of construction related documents that are meant to assist their personnel in supervising highway construction operations conducted within their particular jurisdictions. Although it is generally agreed upon that these various

published materials contain considerable amounts of useful construction knowledge, most industry practitioners acknowledge that timely and effective access of this information is often a significant problem. The emerging technology of hypertext represents a very practical solution to this predicament.

Hypertext, in generic terms, is a nonlinear information management system that allows the user to access information in a more natural way, similar to the way in which that user might store and access information in his or her own mind. This less impeded methodology for accessing information creates a more free flowing environment that enables the user to explore the knowledge base driven more by his or her own interests, rather than by the predefined structure inherent in traditional paper based linear documents. Similar to the discussion of the KBES approach, the balance of this section on hypertext will present a historical background of hypertext, as well as a general overview of this rapidly developing field of computerized technology.

3.3.2 Historical Background

The origin of the hypertext concept is universally attributed to Dr. Vannevar Bush, who among his many accomplishments, served as the Director of the Office of Scientific Research and Development under President Franklin Delano Roosevelt during World War II. In 1945, Bush published an article in The Atlantic Monthly in which he described a purely theoretical device which he called the memex, short for memory extender [Bush, 1945]. Although he did not specifically use the term "hypertext" in any of his writings about the memex, all of the experts in the field of hypertext development agree that Bush's imaginative memex device was the non-computerized forerunner of all of today's computer hypertext systems.

In his now famous article, entitled "As We May Think," Bush wrote of his concerns about the post-war explosion of scientific information which would make it nearly impossible for the research specialists of the day to follow all the new developments associated with a particular field of study. Today this situation is geometrically worse, but even in 1945 Bush realized the need to enable people to access information more effectively than was possible via traditional paper based documentation. He envisioned the memex device, which he explains as follows [Bush, 1945]:

> A memex is a device in which an individual stores his books, records, and communications, and which can be mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory [pp. 106-107].

The mechanism that Bush goes on to describe is an ingenious machine that would be capable of storing millions upon millions of pages of written material reduced onto microfilm. By inputting the code of a particular document into the memex, via a keyboard, the user would instantly be able to view the document in question. Furthermore, the memex provided the capability of creating links between various pages of a single document, as well as the ability to access pages from other completely separate sources. This linking of items is described by Bush [1945] as:

> . . . associative indexing, the basic idea of which is a provision by which any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together (by association) is the important thing [p. 107].

Not much was done in the field of hypertext research until the early 1960s, when a young electrical engineer by the name of Douglas C. Engelbart from the Stanford Research Institute, influenced by Bush's article of 1945, began work on a similar vision in which he

saw computers as a means of assisting thought, or as he referred to it, "the augmentation of the human intellect" [Nelson, 1992]. In an article, entitled "A Conceptual Framework for the Augmentation of Man's Intellect," Engelbart [1963] writes of his beliefs that the computer represented a new stage in human development.

> In this stage, the symbols with which the human represents the concepts he is manipulating can be arranged before his eyes, moved, stored, recalled, operated upon according to extremely complex rules--all in very rapid response to a minimum amount of information supplied by the human, by means of special cooperative technological devices. In the limit of what we now imagine, this could be a computer, with which individuals could communicate rapidly and easily, coupled to a three dimensional color display with which extremely sophisticated images could be constructed [p. 14].

Engelbart's ideas, as presented in his 1963 article, led to the development, in 1968, of a system which he named NLS (oN Line System). NLS according to Engelbart, was an experimental tool designed to aid his research group in their efforts by [Engelbart and English, 1968]:

> . . . placing in computer store all of our specifications, plans, designs, programs, documentation, reports, memos, bibliography and reference notes, etc., and doing all of our scratch work, planning, designing, debugging, etc., and a good deal of our intercommunication, via the consoles [p.396].

These consoles were very sophisticated by the standards of the late 1960s and included television imaging, as well as a variety of input devices, the most famous of which is known today as a "mouse" [Conklin, 1987].

Concurrent with Engelbart's development of NLS, which has evolved over the years and is now called Augment, another hypertext pioneer by the name of Ted Nelson began work on his own personal concept of "augmentation," emphasizing "the creation of a literary environment on a global scale." In 1965 Nelson coined the term "hypertext" in describing

the nonlinear nature of text based storage and retrieval represented by his conceptual "Project Xanadu" [Conklin, 1987; Parsaye et al., 1989].

Some of Nelson's early efforts on Project Xanadu were accomplished while he was affiliated with Brown University in the mid to late 1960s. Although Project Xanadu has only recently begun to find limited commercial applications through its sale in 1988 to Autodesk, Inc., a large software development company, the work conducted by Nelson while at Brown University directly influenced the development of the world's first computerized working hypertext system. A colleague of Nelson's, a man by the name of Andries van Dam, is generally given credit for heading up the research group that unveiled this hypertext system in 1967. This system, which was called "The Hypertext Editing System," ran in a 128K memory partition of a small IBM System 360 mainframe computer and was funded by an IBM research contract. Upon completion of the project, the system was sold by IBM to the Houston Manned Spacecraft Center, where it was subsequently used to produce a variety of documentation for the Apollo space missions [Conklin, 1987; Nielsen, 1990].

For the better part of the next twenty years, work continued on the development of a number of hypertext systems, however, with the exception of very limited commercial applications, these programs compromised in-house endeavors utilized only by the institutions where the systems were originally designed. By the early 1980s commercial versions of some of these research oriented projects did begin to come to the general marketplace. These early hypertext systems, such as NoteCards, developed by the computer scientists at Xerox PARC (Palo Alto Research Center), were designed to run on workstations [Berk and Devlin, 1991]. The requirement of workstations was due to the fact that at this time, personal computers, although in existence, had not yet developed enough internal power to run such systems.

The first mass marketed, personal computer based, hypertext system that achieved any level of commercial popularity was a program known as Guide. Guide, which began as a research project at the University of Kent at Canterbury in 1982 [Parsaye et al., 1989], was introduced in 1986 by a software company called OWL (Office Workstations Limited). Originally, Guide only ran on Macintosh computers, but shortly after its release in 1986, a version that would run on IBM compatible machines under the Windows operating system was developed [White, 1992]. However, it was not until the release of Hypercard by Apple in 1987 that the concept of hypertext truly became mainstream.

Although an adequate programing platform in its own right, the real impetus for Hypercard's surge to the forefront of the hypertext industry was a decision by Apple to bundle Hypercard, free of charge, into the operating system of every Macintosh computer sold after 1987. What this has done obviously, is to ensure that every Macintosh user who purchased their machines after 1987 has access to Hypercard whether or not they initially showed any interest in the software. Apple's visionary marketing approach has led to Hypercard becoming by far the most widely used hypertext system to date, claiming, as of 1991, a world wide user base of literally millions [Bielawski and Lewand, 1991;Woodhead, 1991].

3.3.3 Generalized Overview of Hypertext

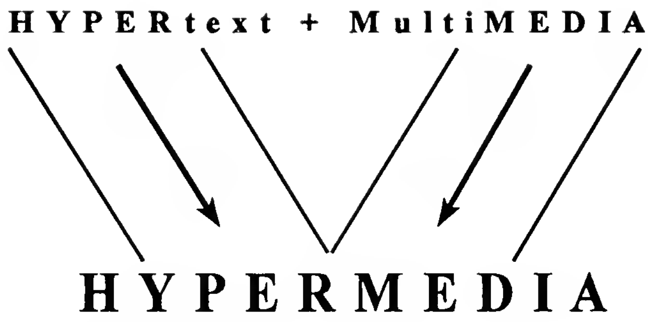
3.3.3.1 Definitions

3.3.3.1.1 Hypertext. Any discussion of the term "hypertext" would be somewhat remiss if it did not include the observations of Ted Nelson, the man who originally invented the word. From one his early publications on the subject, Nelson [1967] suggests the following definition:

> Hypertext is the combination of natural-language text with the computer's capacity for interactive branching or dynamic display, *when explicitly used as a medium*. Or, to define it more broadly, "hypertext" is the generic term for any text which cannot be printed (or printed conveniently) on a conventional page, or used conveniently when bound between conventional covers. "Nonlinear text" might be a fair approximation [p. 13].

Probably the easiest way to explain what hypertext is, is to contrast it with traditional text. Traditional text, whether paper based or electronic, is sequential in nature, having a linear structure defining the order by which the document is intended to be read. Hypertext, on the other hand, is non-sequential, and therefore can allow the reader to explore the document in any order he or she chooses, driven more by personal interest than document structure.

3.3.3.1.2 Hypermedia. Back when Nelson first began using the term hypertext, he was basically describing plain-text electronic documents. However in today's multimedia landscape, an electronic document has taken on a much wider definition. More than just conventional text, contemporary computerized documents can also contain graphics (drawings and pictures), animation, audio, video, as well as multitasking references to other computer programing routines external to the particular document being viewed. Therefore, considering this expanded version of what constitutes an electronic document, some of the leading experts in the field of hypertext research, prefer to use the term "hypermedia" as a means of highlighting the multimedia aspects of their developmental systems. Figure 3.3 presents an illustration representing this idea of hypermedia as being a fusion of hypertext plus multimedia [Howell, 1992].



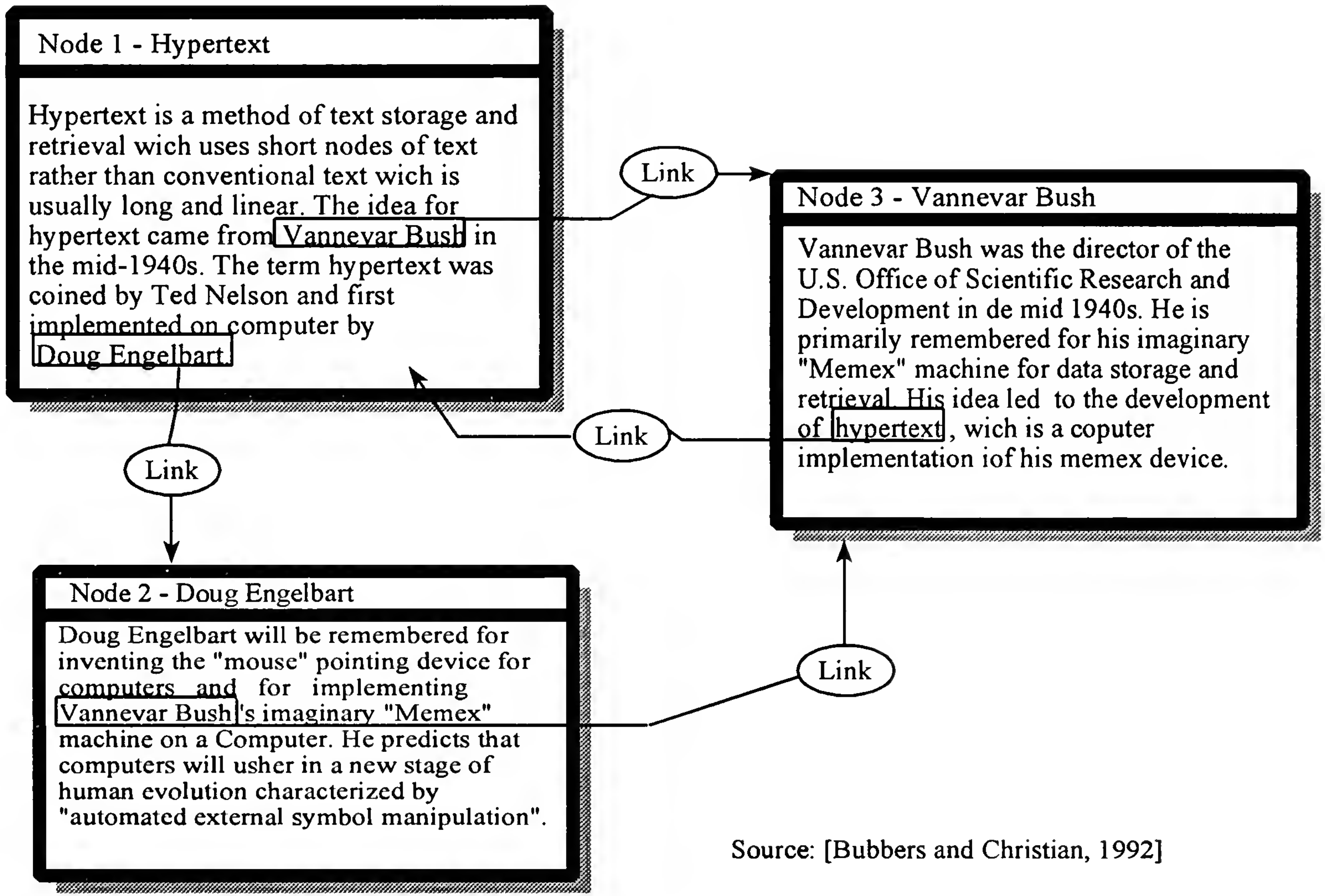
Source: [Howell, 1992]

Figure 3.3 - Hypermedia as a Fusion of Hypertext and Multimedia

3.3.3.1.3 "Hypertext"--selected as the generic preference. Whether one calls it hypertext or hypermedia, the theory is the same, that being the construction of a nonlinear network of linked pieces of information which are presented in such a fashion as to enable a user to navigate through this network, accessing desired information in a more natural and associative manner. Given that there does not appear to be any overwhelming necessity to distinguish between these two terms, it has been decided that the convention that will be adopted for this dissertation will be that of utilizing these terms rather interchangeably, with preference given to the more traditional terminology of "hypertext."

3.3.3.2 The basic concept of hypertext

The fundamental concept underlying hypertext is rather simple. Information is organized or "chunked" into relatively small, self-contained "nodes" which are connected via "links." Figure 3.4 [Bubbers and Christian, 1992] serves to illustrate this idea, while simultaneously presenting some of the historical background of hypertext as previously discussed. As can be noted from this figure, there are three separate nodes connected by four associative links. The various words surrounded by boxes, for example the names of



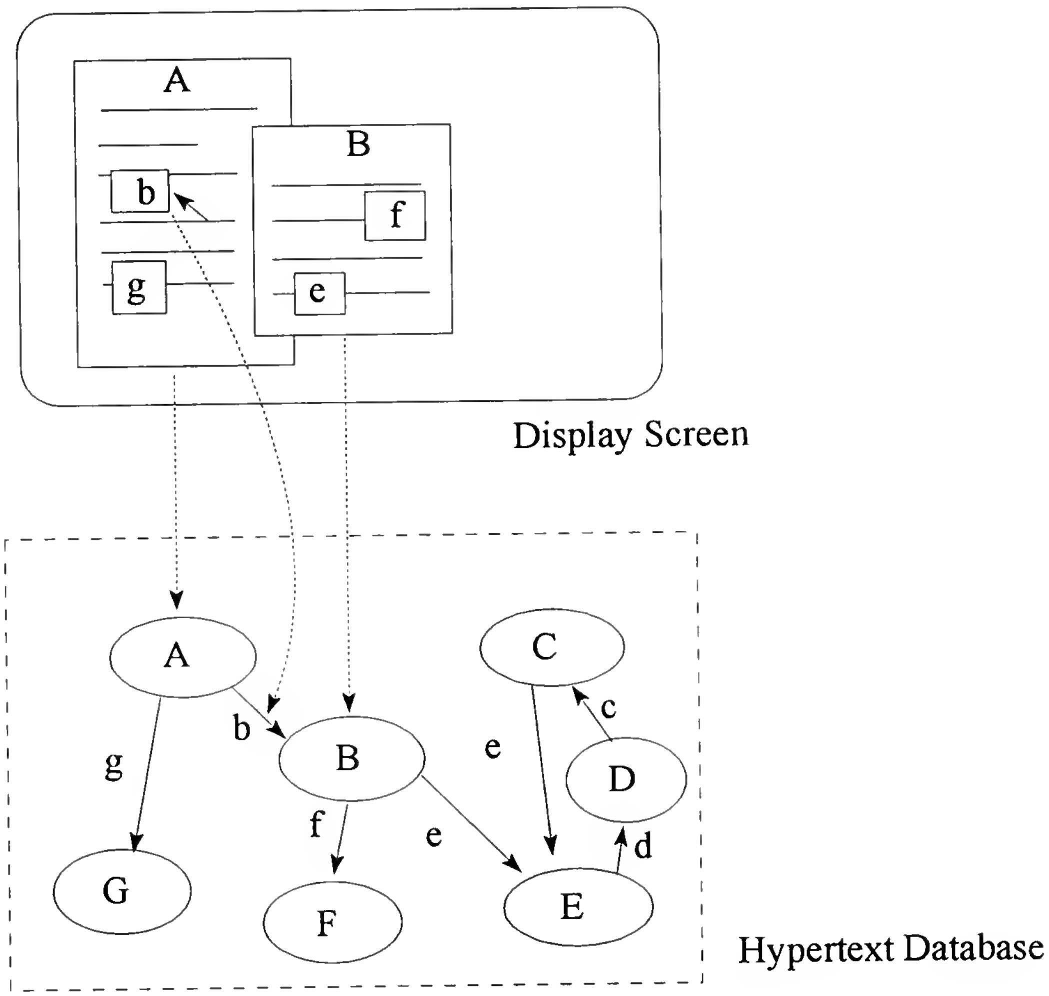
Source: [Bubbers and Christian, 1992]

Figure 3.4 - A Hypertext Network of Three Nodes Connected by Four Links

"Vannevar Bush" and "Douglas Engelbart" in Node 1, are known as "hot keys," "link anchors" or "points." In virtually every contemporary, mouse driven hypertext system, when the mouse is dragged across the hot keys, which are typically delineated from the rest of the text by being displayed in a different color, the cursor changes from it standard shape (usually an arrow head) to a special shape (often a closed right hand with an extended index finger). At this point, the user only has to click the mouse, causing the system to jump automatically via the link to the node that correlates to whichever hot key was clicked on.

Again looking at Figure 3.4, assume the user is located in Node 1 and is reading the information about hypertext. If for example, the user determines that he or she would like more information associated with the highlighted hot key of "Vannevar Bush," a simple click of the mouse will cause Node 3 to immediately pop up for viewing. Although Figure 3.4 illustrates a case involving only plain-text based nodes, utilizing the new generation of multimedia hypertext systems, a skilled developer could have programed the system to access for example, a picture of Vannevar Bush, an audio recording of his voice, or maybe a film clip, if one existed. Referring back to Dr. Bush's landmark article, "As We May Think" [Bush, 1945], published over 50 years ago, it is truly amazing to note just how similar today's hypertext systems are to his imaginative memex device.

As previously noted in the discussion of expert systems presented earlier in this chapter, one of the standard methods for representing knowledge within the knowledge base of a generic KBES was the utilization of semantic networks, also known as semantic nets. Waterman [1986] describes these structures as a collection of points, which are called "nodes," connected by various links, which are commonly termed "arcs" in the semantic network vernacular. Figure 3.5, reproduced from Jeff Conklin's definitive article,



Source: [Conklin, 1987]

Figure 3.5 - Correspondence Between Display Screen and the Hypertext Database

"Hypertext: An Introduction and Survey" [Conklin, 1987], illustrates what he describes as the method by which a typical hypertext system establishes "correspondence between windows and links in the display, and nodes and links in the database." From this figure it can be seen quite readily that conceptually speaking, the notion of hypertext is intimately related to the idea of semantic nets. This being the case, it is apparent that hypertext is more than simply an innovative word processing paradigm. Rather hypertext is by all accounts a knowledge representation tool in its own right, capable of storing and representing knowledge both in the nodes themselves, and through the associative linkage structure that connects these discrete nodes.

3.4 Database Management Systems

3.4.1 General Comments

As was established in the previously presented review of hypertext systems, one of the fundamental and most appealing features associated with hypertext is the free flowing environment this class of software provides for exploration and navigation through a particular base of knowledge and information. However, this unstructured landscape can often lead to a user experiencing a feeling of disorientation, commonly referred to as being "lost in hyperspace." One possible method of overcoming this predicament is to incorporate certain aspects of modern database management systems (DBMS), as a means of providing structure to the inherently unstructured world of hypertext.

The following sections will present a closer look at the historical background associated with the emergence and evolution of contemporary DBMS. Additionally, the three most prominent models of data structuring will be discussed, with special attention

being paid to the relational model, since it is this model which has come dominate today's personal computing DBMS software packages.

3.4.2 Historical Background

The history of DBMS dates back to the early 1960s, when a number of individual corporations in the United States began to produce programs that were created in order to solve in-house data related problems specifically encountered by these particular companies. Probably the most famous of these early efforts was a system developed in 1962 by the General Electric Company (GEC), which was called the Integrated Data Store (IDS) [Beynon-Davies, 1991]. Several years later B.F. Goodrich expressed significant interest in the IDS package, however IDS had been designed to only run on the GEC brand of mainframe computers. Since these computers were not compatible with B.F. Goodrich's IBM (International Business Machines Corporation) systems, they decided to rewrite IDS so that it would operate on the newly released IBM System 360 family of computers. Soon after beginning work on translating IDS, B.F. Goodrich entered into a marketing agreement with a man by the name of John Cullinane, and together they launched the IDMS DBMS which became one of the dominant DBMS for IBM mainframes throughout the 1970s and 1980s [Brodie and Manola, 1989; Beynon-Davies, 1991].

Development of IDS and the subsequent release of IDMS represented the maturation of the network model of DBMS. The network model, however, was only one of three basic models of data structuring that were evolving somewhat simultaneously. Another of these data structuring techniques being researched during the 1960s was the hierarchal model. In 1965, in response to the massive information handling requirements associated with the Apollo moon program, North American, which later became Rockwell International

Corporation, and IBM co-developed a hierarchal model DBMS that eventually was released by IBM in 1970 under the name of IMS (Information Management System) [Cardenas, 1985; Parsaye et al., 1989].

At about the same time that IBM was developing their IMS DBMS, another IBM computer scientist by the name of Dr. E. F. Codd, located at the IBM Research Laboratory in San Jose, California , began work on a general purpose programming language based on set theory and logic, which he called relational programming [Brodie and Manola, 1989]. In 1970, Codd published his landmark article, "A Relational Model of Data for Large Shared Data Banks" [Codd, 1970], which established the relational model on which all subsequently developed relational DBMS were to be based. The relational model did not initially meet with wide spread acceptance, and by the mid 1970s the DBMS landscape had become dominated by the other two models of the network and hierarchal data structuring techniques.

Although originally not very popular, relational modeling gradually did become more recognized as a legitimate structure for DBMS, and by 1976 IBM, through its research center in San Jose, California, was able to develop System R [Astrahan et al., 1976], which became the first working relational DBMS for mainframe computers. Another prominent experimental mainframe relational DBMS released around the same time as System R, was a program called INGRESS [Stonebraker et al., 1976], which was developed at the University of California, Berkeley.

The relational model of DBMS continued its existence almost exclusively within the bounds of university and other research institute settings, until 1983, at which time IBM unveiled DB2, their first commercially released relational DBMS for mainframe computers,

which was a direct outgrowth of their earlier experimental work with System R [Salzberg, 1986]. Approximately at the same point in time, a software company by the name of Ashton-Tate released dBASE II, which went on to become the dominant DBMS for the newly emerging personal computing market. According to Brodie and Manola [1989], by 1988 over 2.7 million copies of the dBASE relational DBMS software package for personal computers had been sold.

3.4.3 Generalized Overview of Database Management Systems

3.4.3.1 Definitions

3.4.3.1.1 General comments. To accurately describe exactly what is a database management system (DBMS), a number of database terms and their usage will be presented first, followed by a working definition of a DBMS.

3.4.3.1.2 Data. Data, independently speaking, are nothing more than a collection of facts and figures, that by themselves lack any real significance. All data within a database can be broken down into two main categories, namely alphanumeric data and numeric data [Date, 1990]. Alphanumeric data consists of alphabetic characters (the letters A through Z) and numerical characters (the numbers 0 through 9), as well as a variety of specialized symbols such as the pound sign (#) and the dollar sign ($), to name two. Numeric data, on the other hand, are strictly a set of numeric digits that can be quantified. Although when stored in a database, both alphanumeric and numeric data represent information, these two classifications take on different roles in their applications. The numeric data within a database are used as numbers in computational operations, while alphanumeric data can only be used as strings of text for identification and labeling purposes.

3.4.3.1.3 Fields, records, and files. In a database, the smallest unit of data, whether alphanumeric or numeric, is commonly referred to as either a "field," a "data item" or an "attribute." A collection of these "fields" constitutes a logical "record," also known as an "entity." A "file" is an assortment of occurrences of the same "record" types [Cardenas, 1985].

3.4.3.1.4 Database. A database can be described as a bank of "records" stored in "files" interrelated by a means of specific relationships. A database is basically a repository for stored data which is both integrated and shared [Date, 1990]. All database systems can be characterized by their efforts to achieve the following four properties [Beynon -Davies, 1991]:

1) *Data Independence*--Due to the concept of shared data, the data in a database must be independent of the storage structure and access strategies.

2) *Data Integration*--Again because of sharing capabilities, a database should contain as little duplicated or unused data as possible.

3) *Data Integrity*--Given that numerous applications are intending to interact with a particular database, it is extremely important that the data must be maintained at a high level of consistency and accuracy [Cardenas, 1985].

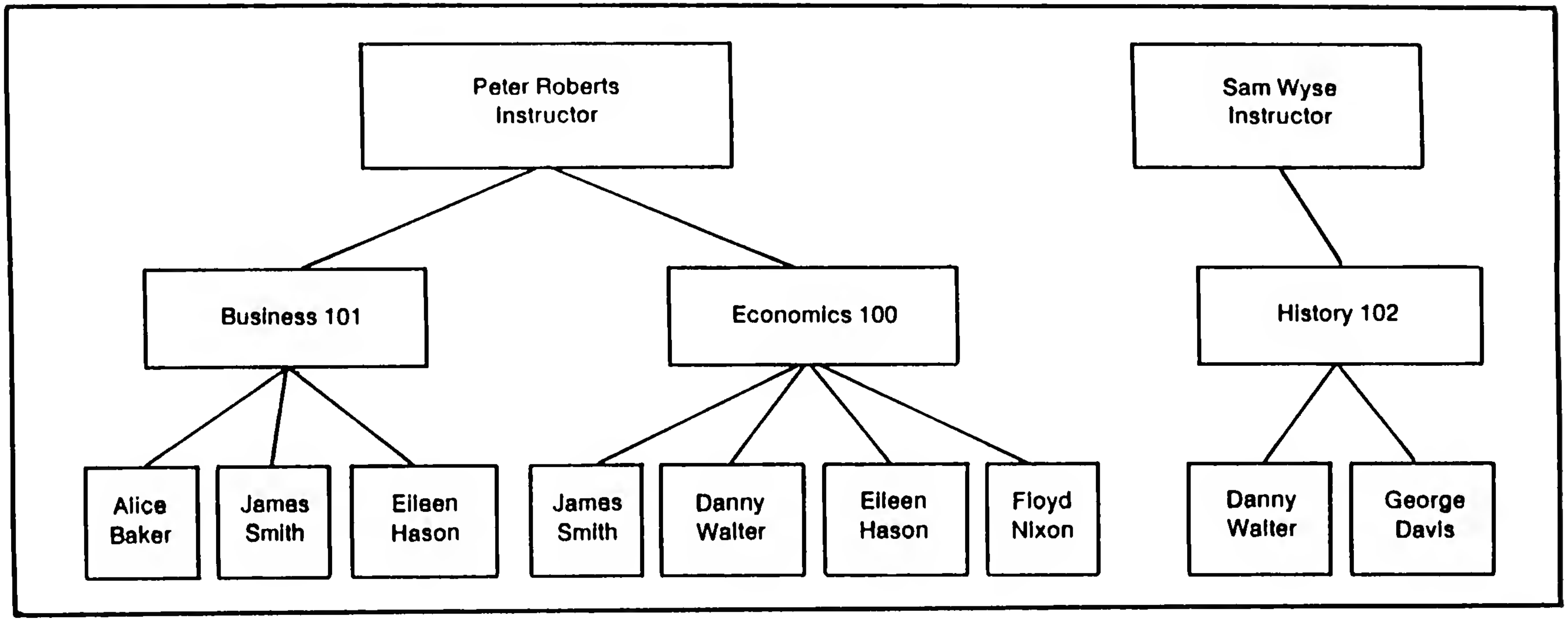
4) *Separate Logical and Physical Views*--What this implies is that a database systems should attempt to separate the end-user's view of the data from the data's physical computerized representation.

3.4.3.1.4 Database management system. In its most generic form, a database management system (DBMS) is a system capable of supporting and managing an integrated database. This suggests, that basically a DBMS is a family of software applications which have been developed to act as an interface between the end-user and all system interactions with the database.

3.4.3.2 Data modeling structures for contemporary database management systems

3.4.3.2.1 General comments. The fundamental component of any DBMS is the method by which the data within the database is organized and structured. In the commercial world of DBMS, the marketplace is still dominated by the three traditional data modeling techniques of the network model, the hierarchal model, and the relational model, with the relational model having almost exclusively captured the personal computing market. It should be noted at this point, that there does exist a number of other data modeling techniques such as semantic models, entity-relationship diagrams, and most notably object-oriented designs [Stonebraker, 1988 Martire and Nuttall, 1993], which recently have experienced significant research attention [Parsaye and Chignell, 1993]. In fact currently there are several commercially available object-oriented DBMS software packages available, the first and probably most established of which is a program called GemStone, marketed by a company by the name of Servologic [Beynon-Davies, 1991; Parsaye and Chignell, 1993]. However, for the purposes of the following discussion on data modeling, only the three prominent techniques (network, hierarchal and relational) will be examined further.

3.4.3.2.2 The hierarchal model. The hierarchal model, sometimes referred to as the file system, is the oldest and most rigid of the three standard database modeling techniques [Date, 1990]. Figure 3.6 [Chou, 1985] illustrates a typical hierarchal representation of the different relationships among the data fields associated with the instructors, the classes, and the students. The relationships represented in this figure are limited to strictly one-to-one associations. For example, the class "Business 101" is directly related to the instructor "Peter Roberts" on a one-to-one basis. This connection can also be defined in terms of what is known as a parent-child relationship [Martire and Nuttall, 1993]. Referring again to the



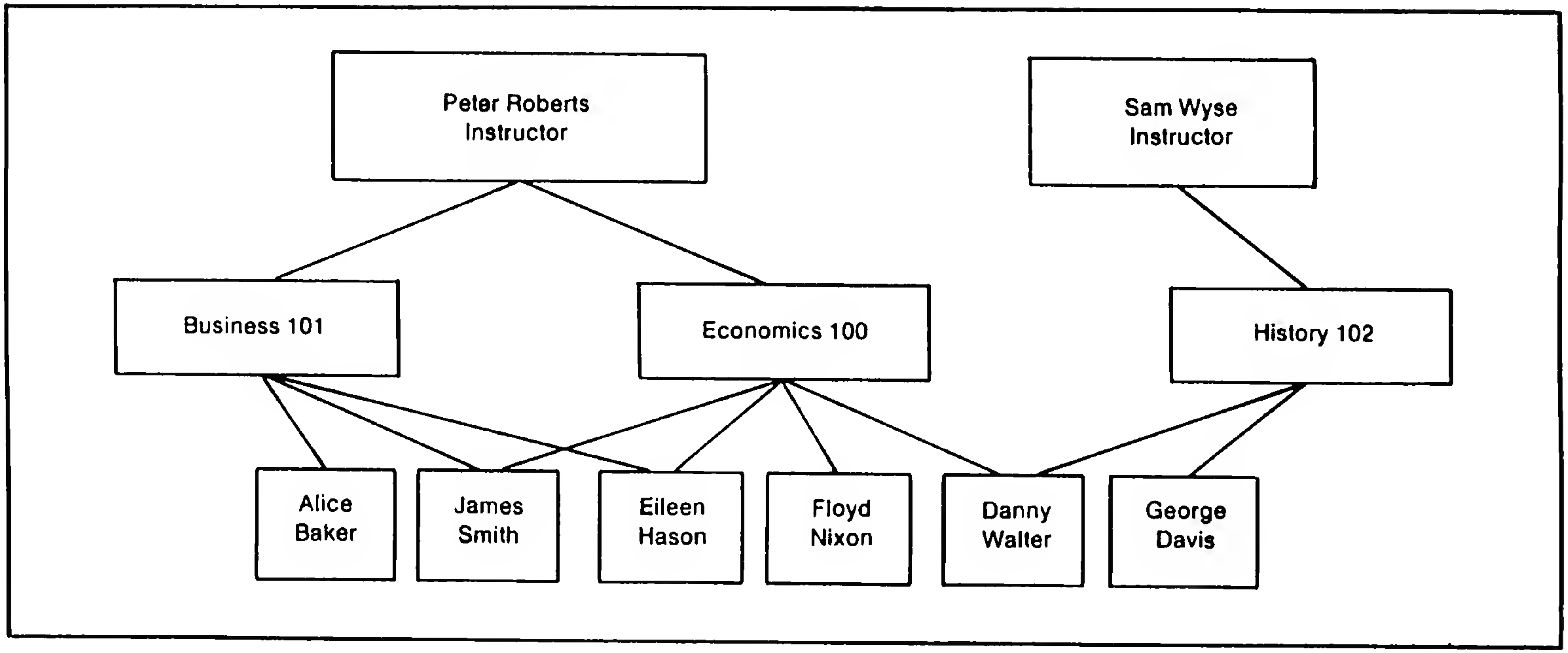
Source: [Chou, 1985]

Figure 3.6 - Typical Representation of the Hierarchal Model

figure, and in terms of the parent-child metaphor, the instructor "Peter Roberts" is said to be the parent of the class "Business 101," which is the child.

3.4.3.2.3 The network model. One of the inherent disadvantages associated with the hierarchal model is that of data redundancy, which is a result of this model's strict one-to-one architectural structure. As an example of this, notice that in Figure 3.6, due to the rigid structure, three of the student data items ("James Smith," "Eileen Hason," and "Danny Walter") must be appear twice in order to satisfy the model. The network model of data structuring was developed in large part to address this problem [Taylor, 1989]. Figure 3.7 [Chou, 1985] depicts the same database as that of Figure 3.6, except for the fact that in Figure 3.7, the data is structured based on the network model. Examination of this figure demonstrates that in fact this model does eliminate data redundancy, in other words, in the network model, every data item is unique. However this aversion of data redundancy does come with a price, namely a much more complex linkage structure.

3.4.3.2.4 The relational model in general. In both the hierarchal and network models, relationships between data items are strictly controlled by their explicit links, or record instances as they are sometimes referred to [Woodhead, 1991]. These links are represented in Figures 3.6 and 3.7 as the solid lines connecting the various data items. This static feature creates a situation wherein navigation through and/or manipulation of the data, not to mention the problems associated with adding, deleting, or modifying a record, require the services of a very skillful database programmer. These difficulties are all but eliminated under the relational model, due to the fact that the data is structured in terms of a two dimensional tabular matrix consisting of a set of named columns, or fields, and an arbitrary number of rows, also known as records. This highly intuitive structure, which is simply a



Source: [Chou, 1985]

Figure 3.7 - Typical Representation of the Network Model

common table, enables a non-sophisticated user to rather easily set up and manipulate considerable amounts of data in a very interactive and natural fashion [Chou, 1985; Woodhead, 1991].

3.4.3.2.5 The relational model as illustrated in Figure 3.8. Figure 3.8 represents the same set of data items as presented in Figures 3.6 and 3.7, except this database is structured in terms of the relational model. The relational table in Figure 3.8 is organized into nine rows, which are also called tuples [Beynon-Davies, 1991] or records, and three columns, each corresponding to a distinct field of data, which in this case are labeled Instructor, Class, and Student. As each data record is entered, it is sequentially and automatically given an arbitrary number, which for this relational table would be a number between 1 and 9, depending on the order of entry. Each of the nine records is assigned a single corresponding attribute within each of the three data fields of Instructor, Class, and Student. This simple tabular structure therefore serves as a methodology of creating nine uniquely identifiable database records. Parsaye et al. [1989] rightfully note that it is this "theoretical purity" and close relationship to natural logic that more than any other factor has propelled the relational model to the forefront of today's DBMS software packages, especially in the realm of personal computers where the users often tend to be less sophisticated.

3.4.4 A Closer Look at Relational Database Management Systems

3.4.4.1 General comments

Since the proposed information management prototype system intended for this dissertation was to be developed under the IBM compatible personal computing environment, and given that, as has previously been noted, relational DBMS have evolved as the dominant force on this platform, logic dictated the selection of this model for further

Row #	Column #1 Instructor	Column #2 Class	Column #3 Student
1	Peter Roberts	Business 101	Alice Baker
2	Peter Roberts	Business 101	James Smith
3	Peter Roberts	Business 101	Eileen Hason
4	Peter Roberts	Economics 100	James Smith
5	Peter Roberts	Economics 100	Danny Walter
6	Peter Roberts	Economics 100	Eileen Hason
7	Peter Roberts	Economics 100	Floyd Nixon
8	Sam Wyse	History 101	Danny Walter
9	San Wyse	History 101	George Davis

Source: [Chou, 1985]

Figure 3.8 - Typical Representation of the Relational Model

examination. Presented next will be a closer look at some of the key points associated with managing data in a relational DBMS.

3.4.4.2 Data manipulation within relational databases

3.4.4.2.1 Operating on relations. One of the distinguishing characteristics of the relational model, as opposed to the hierarchal or network model, is that in relational databases, the data manipulation is designed to operate on entire files (relational tables) of data, rather than on individual records or fields within a file. The term manipulation, as used here, refers to the types of operations that a user can perform on data stored in a relational database. This manipulation of the relational model consists of a set of operators collectively known as the relational algebra [Beynon-Davies, 1991].

3.4.4.2.2 The relational algebra. The relational model basically consists of a list of relations and their associated attributes [Date, 1990]. Data retrieval within this model is accomplished by using the relational algebra as a means of manipulating these relationships. Parsaye and Chignell [1988] specify the five fundamental operations in the relational algebra as follows:

1) *Selection*--Selects certain rows from a table.
2) *Projection*--Removes certain columns from a table.
3) *Product*--Multiplies two tables together.
4) *Union*--Adds two tables together.
5) *Difference*--Subtracts one table from another table.

3.4.4.2.2 Structured Query Language. With the evolution of the relational model, came the development of higher-order languages designed to provide access to the relational model and extract (retrieve) different data sets depending on the specified request of the user.

Of these data access languages, or commonly referred to as query languages, one in particular, IBM's Structured Query Language (SQL), has come to be accepted as the dominant approach for relational query languages. In fact, in 1986, SQL was adopted by the American National Standards Institute (ANSI) as the official industry standard [Fleming and von Halle, 1989].

3.4.4.2.2 An example of a generic SQL command. As an example of the most fundamental SQL instruction, Date [1989] suggests a generic sample of the SQL command (query) "SELECT" taking the following form:

select < Attribute_1, Attribute_2 ... Attribute_n >

from < Relation_1, Relation_2 ... Relation_n >

where < Condition >

In terms of the relational algebra, from which SQL is a direct descendant [Chorafas, 1989], the SQL "SELECT" command is made up the *select* portion of the query clause which is equivalent to the relational algebra operation of projection. The *from* segment of the "SELECT" statement matches the relational algebra operation of product, while the relational algebra counterpart of *where* is the operation of select.

3.5 Summary and Conclusions

3.5.1 General Comments

Having effected a comprehensive background study of the three technologies of expert systems, hypertext, and database management systems, the next step was to determine what aspects of each were useful for integration into the proposed prototype information management system. The following sections will summarize these observations, focusing on

the aspects deemed worthwhile based on the stated needs of the end user and the anticipated industry sector within which this system will be intended to function.

3.5.2 Considerations Regarding Proposed Integrated Environment

3.5.2.1 General programing requirements

Bielawski and Lewand [1991], co-authors of Intelligent Systems Design Integrating Expert Systems, Hypermedia, and Database Technologies, recognized as one of the definitive books in this newly emerging field of study, suggest that the power of today's IBM compatible and Macintosh personal computers, coupled with the myriad of available developmental tools or "shells," make this platform ideal for the development of integrated computer software systems. This idea, along with the fact that the design of any prototype system should be based on the needs of the end user, led to the selection of the IBM compatible personal computer windows operating system, given that this is the system of choice for practically all of the intended end users, who in the case of this research project, are FDOT construction personnel.

Another point that should be emphasized, is that given that the nature of this research endeavor was more geared towards developing a conceptual systematic approach, rather than undertaking an exercise in conventional computer programming, it was determined that higher levels of programing paradigms should be investigated and utilized whenever possible. This notion will be revisited towards the end of this chapter under the discussion regarding software requirements for the prototype system.

3.5.2.2 Intended knowledge base content as determining factor for hypertext underpinnings

Although this subject will be covered more thoroughly in Chapter 4, a preliminary

understanding of the structural makeup of the intended knowledge base would be required in order to effectively identify which aspects of which technologies were to be utilized. As has previously been mentioned, most of this country's SHAs have over the years amassed a considerable base of construction related documentation, which in essence captures much of the knowledge and expertise possessed by these particular organizations and their personnel. In an effort to utilize the significant investment represented by these documents, it seemed only prudent that the prototype system take advantage of this wealth of information. With this in mind, and considering each of the three technologies analyzed, clearly the proposed approach should utilize hypertext as the backbone of the developmental philosophy for managing this naturally occurring text based bank of construction knowledge and experience.

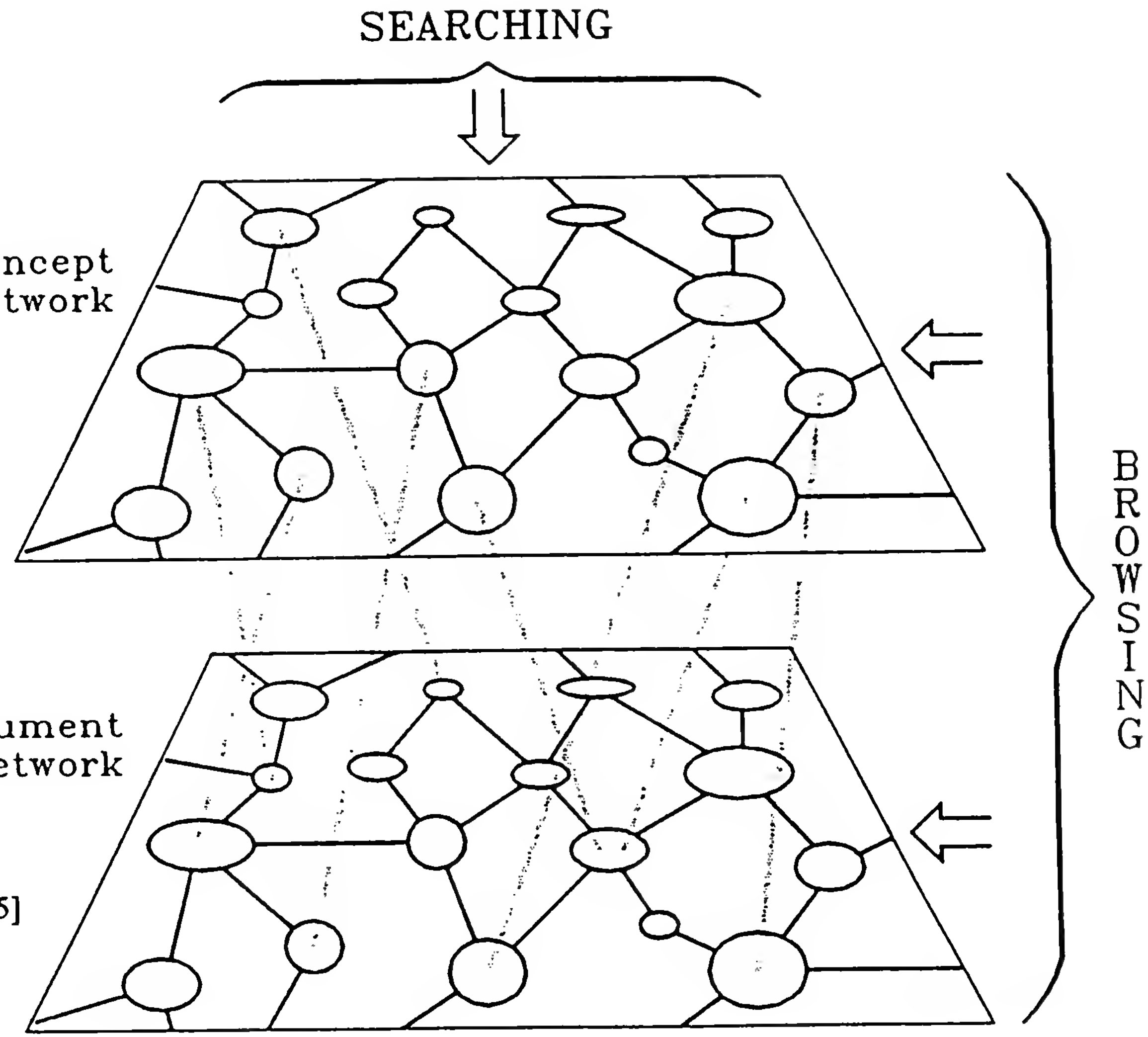
3.5.2.3 Integrating database strategies for added structure

Nanard et al. [1993], conceptually describe hypertext as fundamentally a relational database with unlimited and unrestricted links between the records, fields, and files. This metaphor is highly appropriate to this dissertation's intention of employing database strategies as a method of providing structure to the inherently unstructured environment of a pure hypertext system. From the field of database management, two basic modeling strategies were to be incorporated. The first, was a hierarchal structure based on the traditional hierarchal model as presented earlier in this chapter. The idea here was to embed a one-to-one, hard-wired, parent-child, relational linkage scheme throughout the entire architecture of the hypertexed system of nodes. Details of how this was accomplished will be examined further in Chapter 4.

Inspiration for the other database structuring strategy came from two sources, one of which, the BCOE Advisor system [Roessler et al., 1993], was detailed in Chapter 2. This

system, developed by USACERL, utilizes the commercially available rBASE relational DBMS, along with SQL querying capabilities, as a methodology for storing and retrieving conceptually indexed design review comments. The second basis of influence was a paper, uncovered as a result of this review of published literature, written by Dario Lucarella [1990]. In his article, entitled “A Model for Hypertext-Based Information Retrieval,” Lucarella presents an interesting discussion with respect to the difference between browsing and searching. He describes browsing as characterized by the user knowing “where he is in a network, and wanting to know what information exist at that location.” While when searching the user “presumably knows what he wants, and wishes to know where in the database it is.” Figure 3.9 illustrates Lucarella’s proposed integrated tactic which provides capabilities for both browsing and searching.

Borrowing from these two innovative approaches, the second of the database strategies was formulated in an attempt to utilize the relational model of database management as a method of indexing each node in the prototype hypertext network. In theory, a node could be conceptually linked to a set of attributes based on the informational content that it contained. These nodes could then be stored in a relational table enabling a user to directly query the system in order to access a group of hypertext nodes, specifically related to his or her area of interest, regardless of the nodes physical location within the hypertext network. In other words, a user would not have to blindly explore the network via the hard-wired links, node to node, in search of the desired information. Rather he or she could retrieve all nodes within the system having to do with a particular subject, and then continue navigational browsing from that point forward. Details of the implementation of this strategy will be presented as part of Chapter 5.



Source: [Chou, 1985]

Figure 3.9 - Integrated Hypertext Network With Browsing and Searching Capabilities

3.5.2.4 Utilization of a KBES inference engine for dynamic linking

Assuming that the relational database structuring strategy was attainable, the other somewhat more ambitious proposal was to supplement this static structure with a form of dynamic linking. To reiterate, each table would be established as a relational structure compromised of individual records, each of which corresponding to a single node in the network, conceptually organized in a "controlled indexed" [Carlson, 1989] format. Once this was accomplished, it was envisioned that the system could recognize the particular node where the user was located, search the entire network for all other nodes of related subject matter, and then return a list for the user to browse. The determination of "related" nodes could be accomplished utilizing an embedded generic rule set coupled with a forward chaining inference strategy. Presentation of the fruition of this strategy is also included in Chapter 5.

3.5.3 Software Requirements for Prototype System

Based on the discussion thus far, four general requirements of any potential software development tool have been established as follows:

1) The software must operate under the IBM compatible personal computing windows environment.

2) The software package must have rich and fundamentally underlying hypertext capabilities.

3) The software package must support the relational database model and preferable provide SQL capabilities for querying a relational database. As noted previously, the benefit of SQL is that it has been accepted as the industry standard relational database query language.

4) The software package must be capable of delivering an imbedded KBES inference engine that can employ the forward chaining strategy.

One other item that was previously mentioned earlier in this section, and which will be expanded on at this point, is the concept of fully integrated, higher-level developmental programming tools. As was noted, one of the expressed objectives of the research's software development efforts was the exploitation of commercially available packages, rather than attempting to develop the prototype system using established conventional programming languages such as C++, Pascal, LISP or PROLOG. Although these languages are very powerful, they require inordinate amounts of programming time in relation to functional return on this manpower investment. Under the guise of a construction research project, it is far more important to identify the cutting edge computer technologies and attempt to implement them with respect to construction related issues.

Along this same line of reasoning, it is also highly beneficial to utilize only one vendor's software package rather then attempt to integrate distinct and separate packages developed by different manufacturers. Although all systems that operate under the windows environment theoretically inherit some basic level of platform wide integrative capabilities, typically, experience shows that the dependence of fully seamless integration across software vendors is usually not a recommended practice. The basis of this discussion on the importance of maintaining a single developmental environment, led to the fifth and final requirement for the potential software development tool, which is as follows:

5) If possible, all functional requirements established in points 1) through 4) as listed above, should be accomplished by the use of a single vendor's higher-level windows developmental programing software package.

3.5.4 Final Selection of Software Package for Prototype System

With the established requirements of the potential software package in mind, some of the newest and commercially available developmental programming tools were evaluated.

This original review was accomplished via preliminary searches of appropriate articles found in such computer trade publications as Infoworld, PC Magazine, and Byte. Results of this preliminary review yielded the two candidates as listed below for final consideration for selection as the software package to be utilized:

1) The Intelligence Compiler (I/C)--distributed by IntellegenceWare, Inc., whose president is Kamran Parsaye, principle author of three of the books uncovered during this literature review and referenced throughout this dissertation [Parsaye and Chignell, 1988; Parsaye et al., 1989; Parsaye and Chignell, 1993].

2) KnowledgePro Windows (KPWin)--distributed by Knowledge Garden Inc.

Both of these companies were contacted and from each, a set of demonstration diskettes and a standard manufacture's information package was received. Appendix J contains a copy of the general product sheets associated with these two highly integrated and powerful software packages. Upon completion of the review of the demonstration diskettes and the associated product literature, the final choice was made to proceed with the KPWin software package, namely because it was felt that this programming tool supported a fuller hypertext environment as compared to that of (I/C).

3.5.5 Final Comments

With the literature review complete and the software package selected, the focus of this dissertation would now be shifted from evaluating the efforts of others to initiating work specific to accomplishing the remaining stated objectives of this research endeavor. Presented next in Chapter 4 will be the issues involved in developing the focused base of highway construction knowledge and experience. Chapter 5 will follow with a comprehensive explanation of the development and subsequent testing of the computerized

information delivery system, which from this point on will be referred to as the IN REACH system, an acronym for Intelligent iNformation Retrieval and Expert Advice in the Construction of Highways.

CHAPTER 4
KNOWLEDGE BASE DEVELOPMENT FOR THE IN REACH SYSTEM

4.1 Introduction

As was noted during the earlier discussions regarding knowledge based expert systems (KBES), the task of capturing the knowledge and experience of the domain experts, commonly referred to as knowledge acquisition [Parsaye and Chignell, 1988], is universally recognized as the critical phase in the production of any successful knowledge based system [Waterman, 1986; McGraw and Harbison-Briggs, 1989; Dym and Levitt, 1991]. Fiegenbaum's assessment of the late 1970s, in which he noted that at that time, knowledge acquisition was the "bottleneck" in expert systems development [Fiegenbaum, 1977], still holds true today. This chapter will present a brief look at the traditional approach as compared to this dissertation's modified strategy, with respect to knowledge acquisition. Additionally, this chapter will examine the foundational knowledge base developed for the IN REACH system, as well as include a discussion of the documents utilized along with a presentation of the embedded hierarchal model within the underlying hypertext system.

4.2 The Traditional Approach to Knowledge Acquisition

4.2.1 General Comments

With the proliferation of KBES developmental efforts over the last three decades, the concept of knowledge acquisition has developed into its own separate field of study. Evidence of this can be seen by the fact that today there exist numerous texts [Kidd, 1987; McGraw and Harbison-Briggs, 1989; Adeli, 1990] completely dedicated to this subject. Furthermore, reviews of any of the standard text books on KBES [Parsaye and Chignell, 1988; Dym and Levitt, 1991; Ignizio, 1991] indicate that invariably there are at least one or two chapters on this critical area of expert system development . This representative list of published books does not include the myriad of articles [Cohn et al., 1988; De La Garza et al., 1988; Hanna et al., 1992] that have been published over the last several years in the various technical engineering journals. Presented next will be a brief overview of some aspects of the traditional approach to knowledge acquisition.

4.2.2 An Overview of the Traditional Approach

According to McGraw and Harbison-Briggs [1989, p. 8], knowledge acquisition can be thought of as a process that encompasses "both 1) the task of reducing an exhaustive body of diverse domain knowledge into a precise, easily modifiable set of facts and rules; and 2) the tools and methods that support the system development." Hanna et al. [1992] also take this approach of describing knowledge acquisition as involving the entire operation of constructing a knowledge base. They go on to concisely define what they perceive as the three basic stages of "extracting knowledge and creating a knowledge base" as follows:

1) Familiarization and domain definition stage.

2) Elicitation stage.

3) Organization, encoding and representation.

In their article, entitled "Knowledge Acquisition and Development for Formwork Selection System," Hanna et al. [1992] describe the structured interviewing method, which is by far the most common technique utilized in KBES development, that they employed with respect to the elicitation stage for their knowledge acquisition strategy. Although the "interview" is the method of choice for most knowledge engineers, several other techniques exist. Slatter [1987] presents an overview of what he deems as the six most commonly accepted knowledge elicitation techniques. A summary and short description of his list is as follows:

1) *Interviews*--The most familiar and widely used method. They can be either structured or unstructured individual or group sessions that can be recorded by hand, audio, or video.

2) *Verbal Protocols*--The expert is required to give a verbal commentary on his or her thought process while working through a problem.

3) *Machine Induction*--Generate a database of preclassified examples and allow the machine to induce the rules for the solution of the problem.

4) *Observational Studies*--Similar to verbal protocol, only the expert is not required to maintain a running commentary, rather the expert is simply observed in problem solving situations.

5) *Conceptual Sorting*--This is a cognitive psychology technique of asking the expert to sort individual concepts into groups to form solutional hierarchies.

6) *Multi-Dimensional Scaling (MDS)*--This is another psychology tool that takes conceptual sorting one step further, and attempts to differentiate between closely related concepts within a group.

4.3 The IN REACH Modified Approach to Knowledge Acquisition

4.3.1 General Comments

Referring again to the three stages (Familiarization, Elicitation, and Organization) as set forth by Hanna et al. [1992], the modified approach to knowledge acquisition, as pursued under this research effort, initially paralleled the traditional approach by defining the domain, as detailed in Chapter 2, as "New Bridge Construction" with an emphasis on "Inspection Operations." Continuing on a analogous path, the next step was to become familiar with the domain selected. Concurrent with the research of the literature associated with the selected domain, preliminary interview sessions were begun as part of the elicitation phase. It was at this point that it became apparent that typical structured interviewing techniques would not be feasible for the domain selected due to the breadth of the subject matter encountered. Additionally, during review of FDOT documentation, numerous sources of captured construction knowledge, in the form of FDOT published materials, were uncovered. Given the difficulty with the preliminary interviews, coupled with the wealth of existing departmental documentation, it was decided to modify the traditional approach to the knowledge base development as will be presented next.

4.3.2 An Overview of the Modified Approach

As was just stated, early into this research effort it was determined that a standard rule based expert system would not fully address the stated objectives. It was felt that the inordinate amount of time that would be required to develop a comprehensive bank of knowledge strictly represented as production rules would be very cost ineffective. Based on the preliminary findings, a modified approach to the task associated with developing the

knowledge base was formulated. Deviating from the standard approach, this research effort proposed utilization of existing FDOT published materials as the functional core for the knowledge base of the IN REACH system. In other words, rather than simply using FDOT documentation as a means of domain familiarization, selected sections from these manuscripts were scanned and input directly into IN REACH. These electronic documents would then serve as the foundational basis for the IN REACH system.

As for elicitation techniques for the acquisition of heretofore undocumented construction expertise, it was decided to pursue the development of a post construction conferencing program similar to the that of the U.S. Army Corps of Engineers, as detailed previously in Chapter 2. The particulars of the lessons learned strategy utilized in the knowledge base development for IN REACH will be presented later in this chapter, however, in general, the idea was to supplement the documented base of knowledge with selected lessons learned derived from various post construction conferences. The concept of post construction conferencing seemed to more closely relate to the stated objective of accomplishing a systematic approach to knowledge acquisition, than did traditional interview techniques. In typical one-on-one interview sessions, the information gathered is often highly influenced by the personalities involved, thus generating a rather unsystematic procedural approach. It was felt that in a large organization, such as the FDOT, implementation of a program that would require the members of a particular project team to conduct a meeting at the end of the job, could yield more highly focused comments by means of a more organization-wide systematic process.

As noted in Hanna et al [1992], the third basic stage in the development of a knowledge based system is the organization and presentation of the acquired knowledge. In

a typical KBES this is accomplished by an exhaustive task of encoding the knowledge into a complicated set of production rules. Here again the approach of IN REACH deviated from that of a traditional KBES. Rather than attempt to represent all of the information contained in the document base in terms of rules, the documents themselves, along with the comments collected from the post construction conferences, were utilized to represent the captured knowledge of the organization. IN REACH utilized an underlying hypertext system as a method of storing this collection of text based knowledge. Supplementing this network of nodes were a variety of linking techniques and searching strategies incorporating various aspects of both expert systems and database management systems, as was already discussed in theory in Chapter 3, and whose practical implementation will be presented in Chapter 5.

4.4 The IN REACH Base of Documented Knowledge and Experience

4.4.1 General Comments

As has now been noted several times, a vast majority of the highway construction information that compromises the IN REACH knowledge base is contained in a variety of existing FDOT documents. As part of the process of developing the IN REACH knowledge base, a myriad of Departmental publications were examined for useful information, specifically relating to new bridge construction. The next section presents an overview of the document base of IN REACH, utilizing captured computer screens from the prototype system.

4.4.2 A Closer Look at the Document Base of IN REACH

4.4.2.1 Index of sources index screen for "BRIDGES"

Figure 4.1 illustrates an IN REACH captured screen of the index of sources for the general category of "BRIDGES." As will become readily apparent, the IN REACH prototype system, although capable of handling any number of general categories, for the purposes of this research effort, only the general category of "BRIDGES" has been developed. With this in mind, all references to all screens for the rest of this chapter will always come from within the general category of "BRIDGES." Two important IN REACH conventions should be noted at this point. First, any text that is underlined represents a hot key that when clicked on with the mouse will access that particular node. Additionally, these underlined strings of text actually appear on the IN REACH computer screen as green in color, although obviously this can not be illustrated in a black and white figure. Another convention of IN REACH is that any green underlined string of text in which all characters are capitalized represents an index screen. An index screen, in the IN REACH terminology, is a node that contains a list of other screens that can be accessed from this point. In other words, they are basically menu screens. Referring again to Figure 4.1, which is an example of just such an index screen, an inventory is listed of the ten sources that make up the IN REACH document base. Two of these entries will be covered in the next section of this chapter, lessons learned from post construction conferences. The other eight will be presented next.

4.4.2.2 FDOT Standard Specifications for Road and Bridge Construction

Figure 4.2 represents all of the specification sections from the FDOT Standard Specifications for Road and Bridge Construction [Florida, 1991] that were electronically

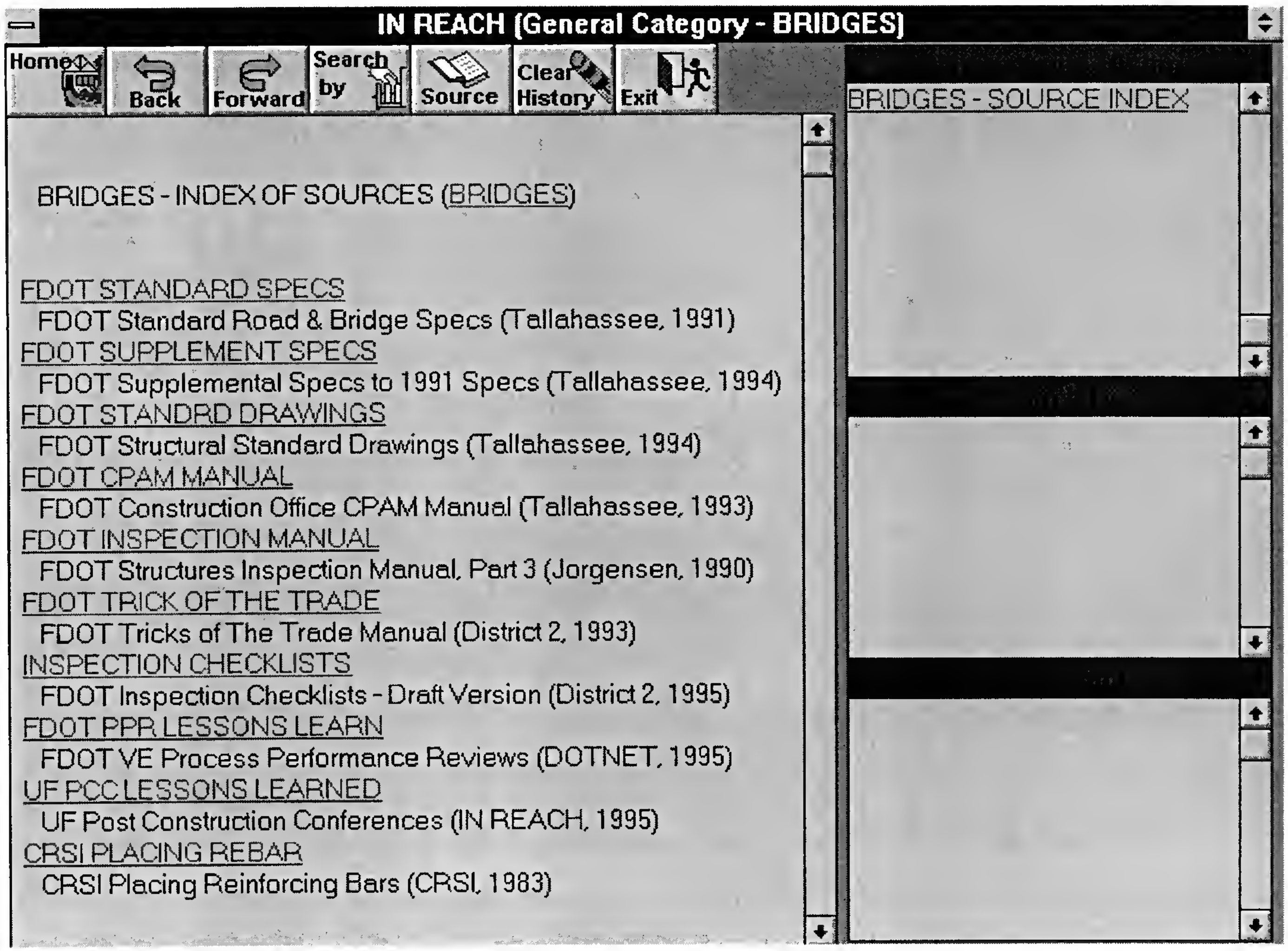


Figure 4.1 - IN REACH Index of Sources Index Screen for BRIDGES

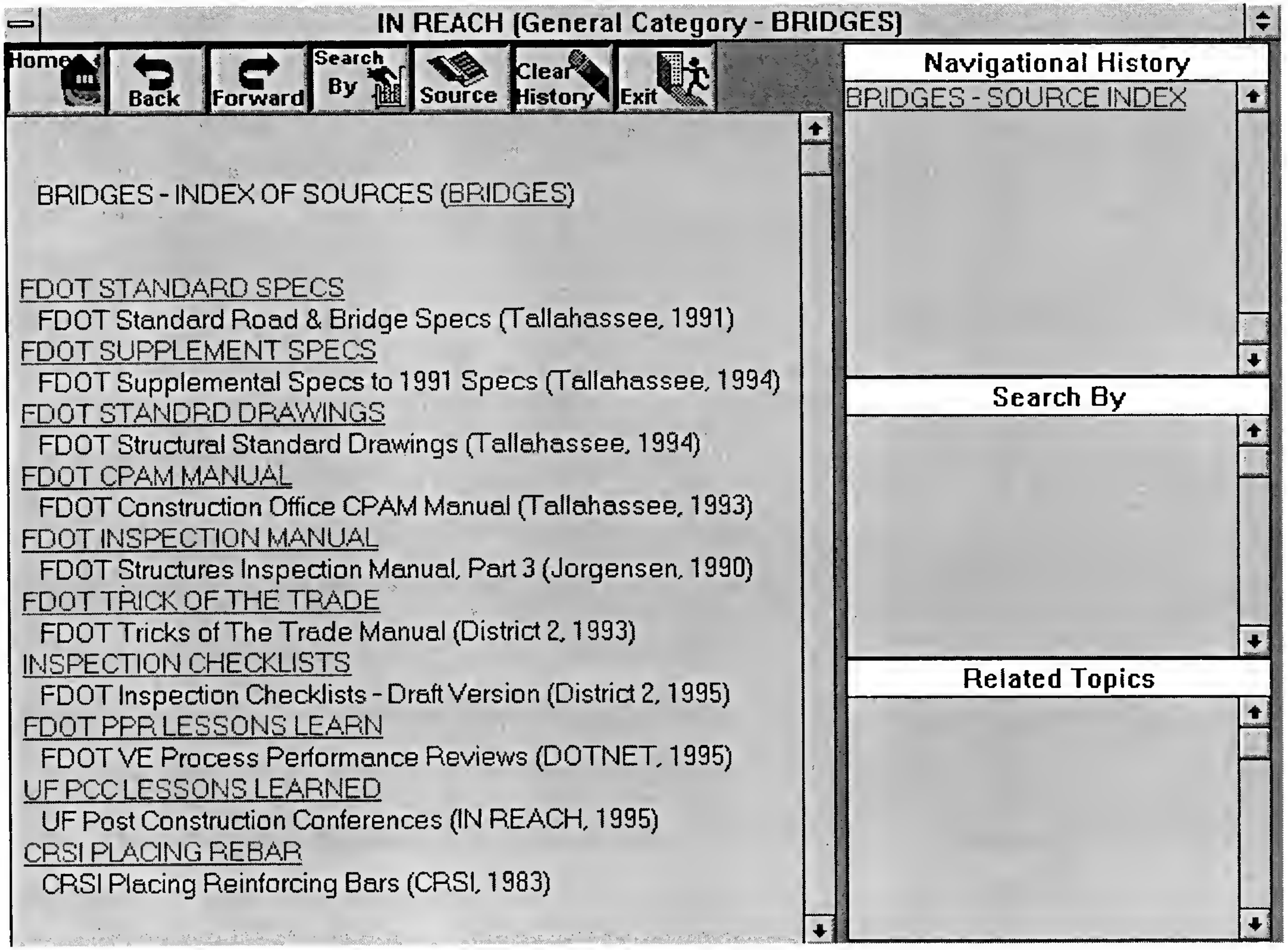


Figure 4.2 - IN REACH FDOT Standard Specs Index Screen for BRIDGES

loaded into the IN REACH document base. This screen is also an index screen, and can be accessed by clicking on its corresponding hot key from Figure 4.1. Given that one of the primary functions of FDOT construction personnel is to insure that construction conducted under their jurisdiction is done so in strict conformance with the plans and specifications, this particular document was heavily utilized in the IN REACH system.

4.4.2.3 FDOT Supplemental Specifications to the 1991 Standard Specifications

Figure 4.3, also an index screen that again can be accessed from the index of sources (Figure 4.1), lists all the sections from the FDOT Supplemental Specifications to the 1991 Standard Specifications for Road and Bridge Construction [Florida, 1994a] that were incorporated into the IN REACH system. The supplemental specifications, as the name implies, are specifications that were developed post release of the 1991 specification book, and as such carry a higher priority.

4.4.2.4 FDOT Structural Standard Drawings

Figure 4.4 is the index screen that provides one method of access to Figure 4.5, which is an image of a portion of the FDOT Design Standard Index Drawing No. 600, sheet 1 of 2 [Florida, 1994b], detailing design standards for precast pile splices. It should be noted that the hot key, listed on Figure 4.4, that corresponds to the image of Figure 4.5, begins with the word "Illustration." Another of the IN REACH conventions is to identify any graphical image by beginning the hot key string name with this word.

4.4.2.5 Office of Construction--Construction Project Administration Manual

Figure 4.6, is the captured index screen for the Office of Construction--Construction Project Administration Manual [Florida, 1993]. To quote from this manual's introduction,

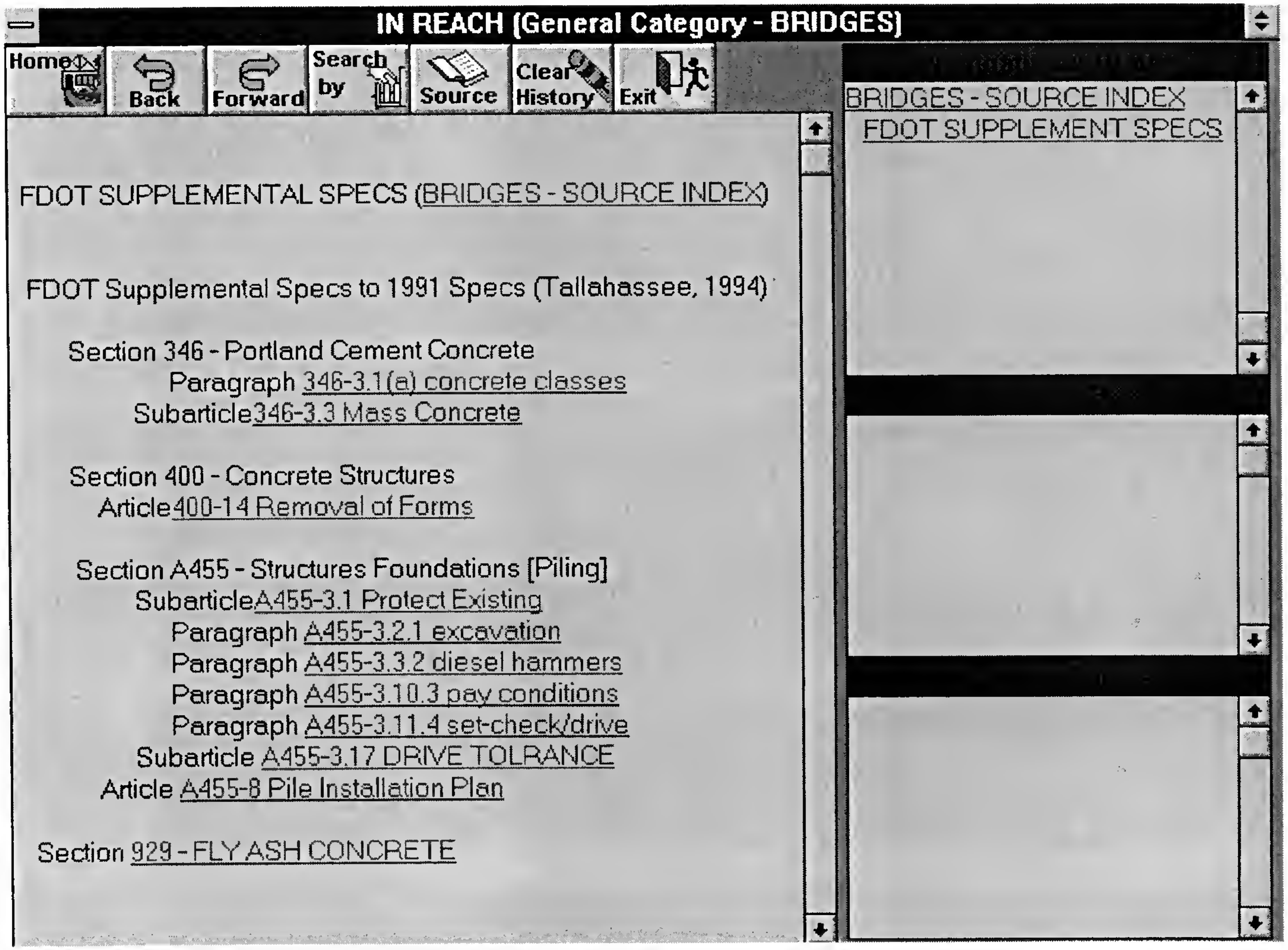


Figure 4.3 - IN REACH FDOT Supplemental Specs Index Screen for BRIDGES

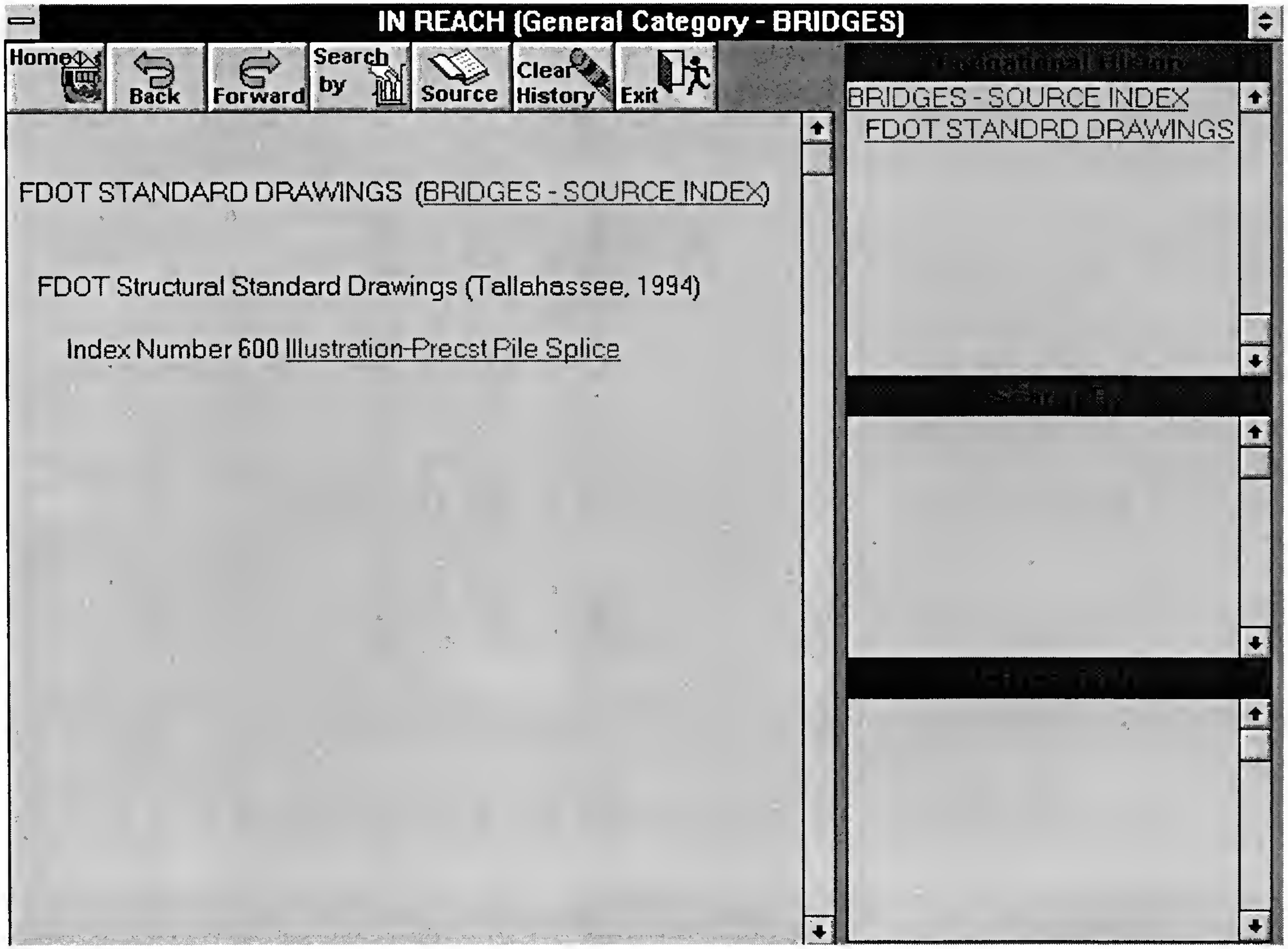


Figure 4.4 - IN REACH FDOT Standard Drawings Index Screen for BRIDGES

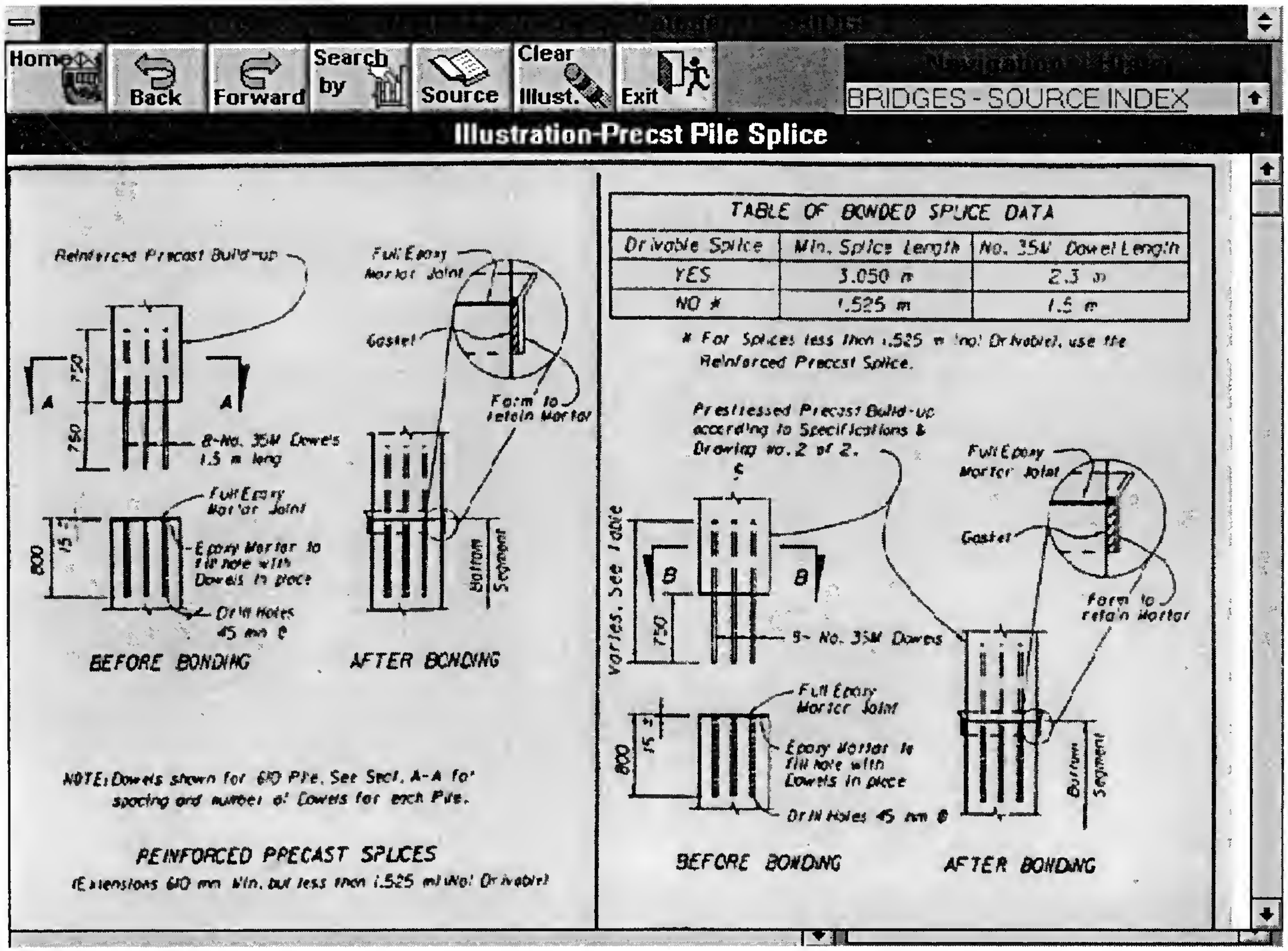


Figure 4.5 - IN REACH FDOT Pile Splices Illustration Screen for BRIDGES

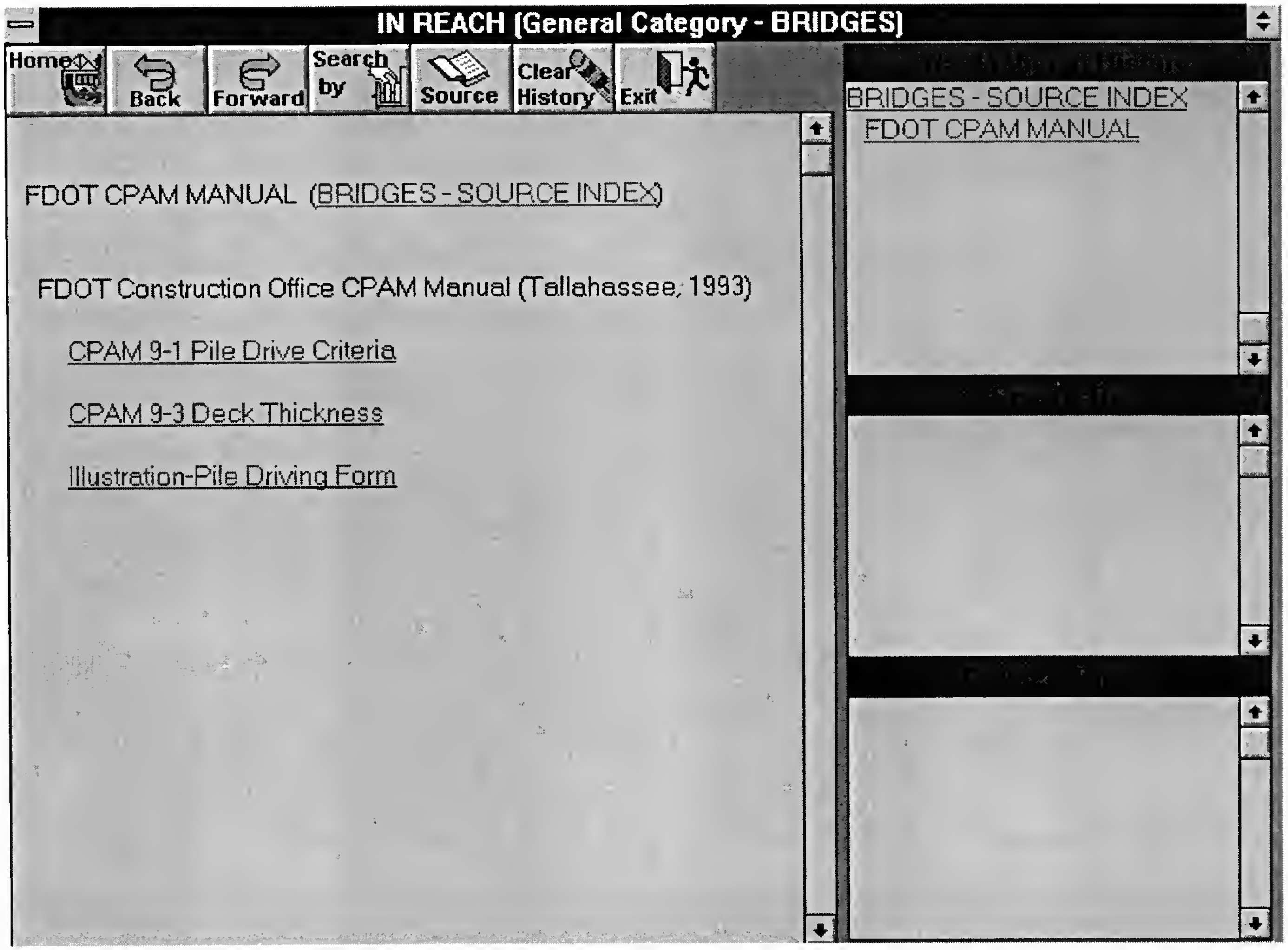


Figure 4.6 - IN REACH FDOT CPAM Manual Index Screen for BRIDGES

"This manual is intended to be used by Construction Inspectors, Project Engineers, Resident Engineers, and other Department personnel involved in the administration of construction contracts." This manual is similar in concept to the New York State Department of Transportation's Construction Supervision Manual [New York, 1984], sections of which were reproduced as Appendix F.

4.4.2.6 Structures Inspection Manual, Part 3

Figure 4.7 is the index screen for the Structures Inspection Manual, Part 3 [Jorgensen, 1990]. This manual is a one of three volumes of a structures inspection self study training course developed by Roy Jorgensen Associates, Inc., a consulting firm out of Buckeystown Maryland.

4.4.2.7 Tricks of the Trade manual

Figure 4.8 displays the index screen for the selected notes gleaned from the bridge section (Section IV) of the Tricks of the Trade [Jacksonville, 1992] manual. This booklet was developed by a Quality Improvement (QI) task team out of the Jacksonville, Florida FDOT District 2 construction office. According to the introductory page of this document, the purpose of this manual was to "establish a list of valuable construction 'tricks of the trade' which will benefit all new FDOT construction employees, including P.E. Trainees." Figure 4.9 details one particular trick of the trade associated with a method for ensuring that the concrete around embedded bridge deck armor joints is properly vibrated. It is interesting to note that the QI task team was made up of eight veteran FDOT construction personnel, who aggregately represented over 270 years of accumulated construction experience.

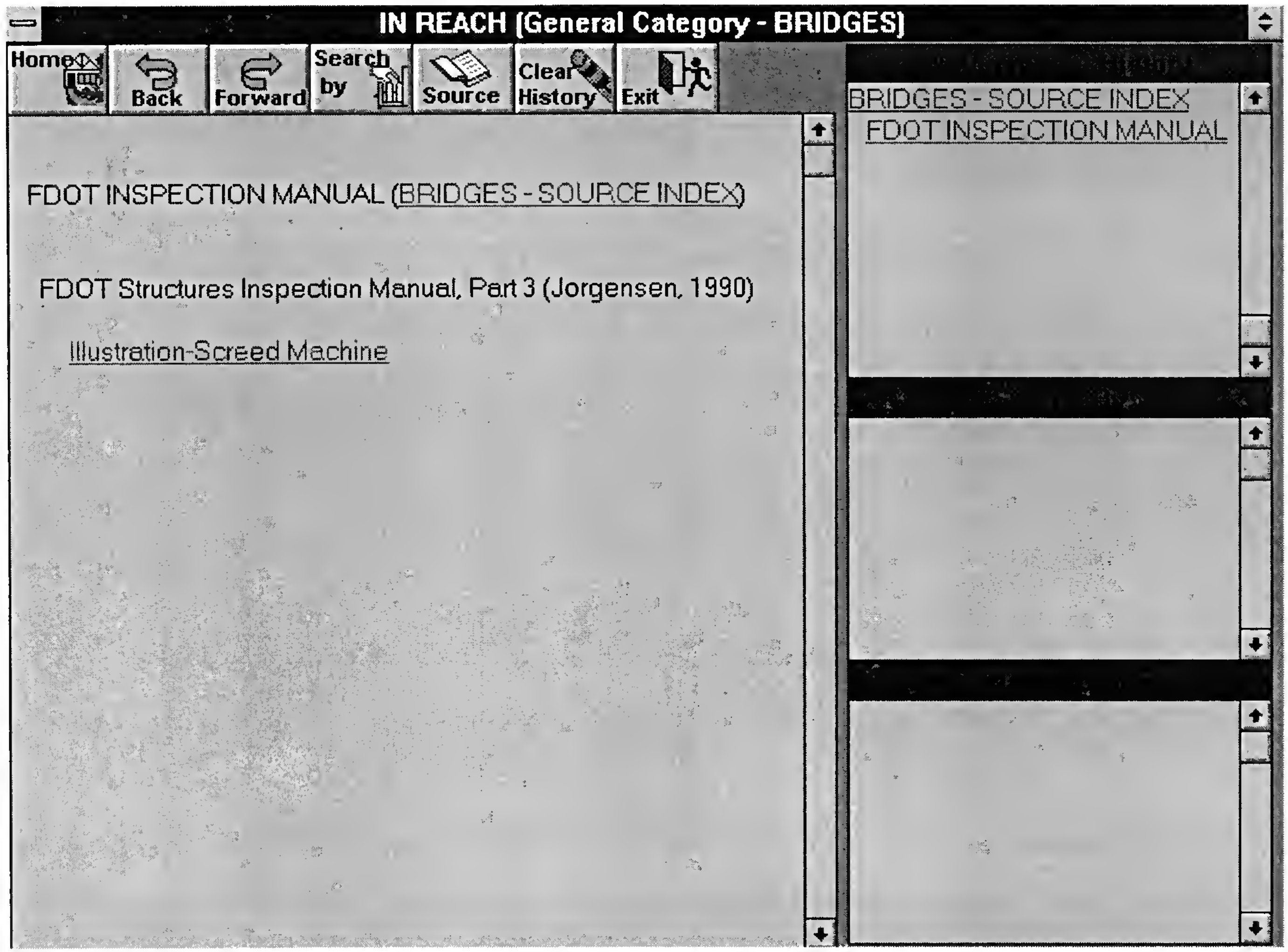


Figure 4.7 - IN REACH FDOT Inspection Manual Index Screen for BRIDGES

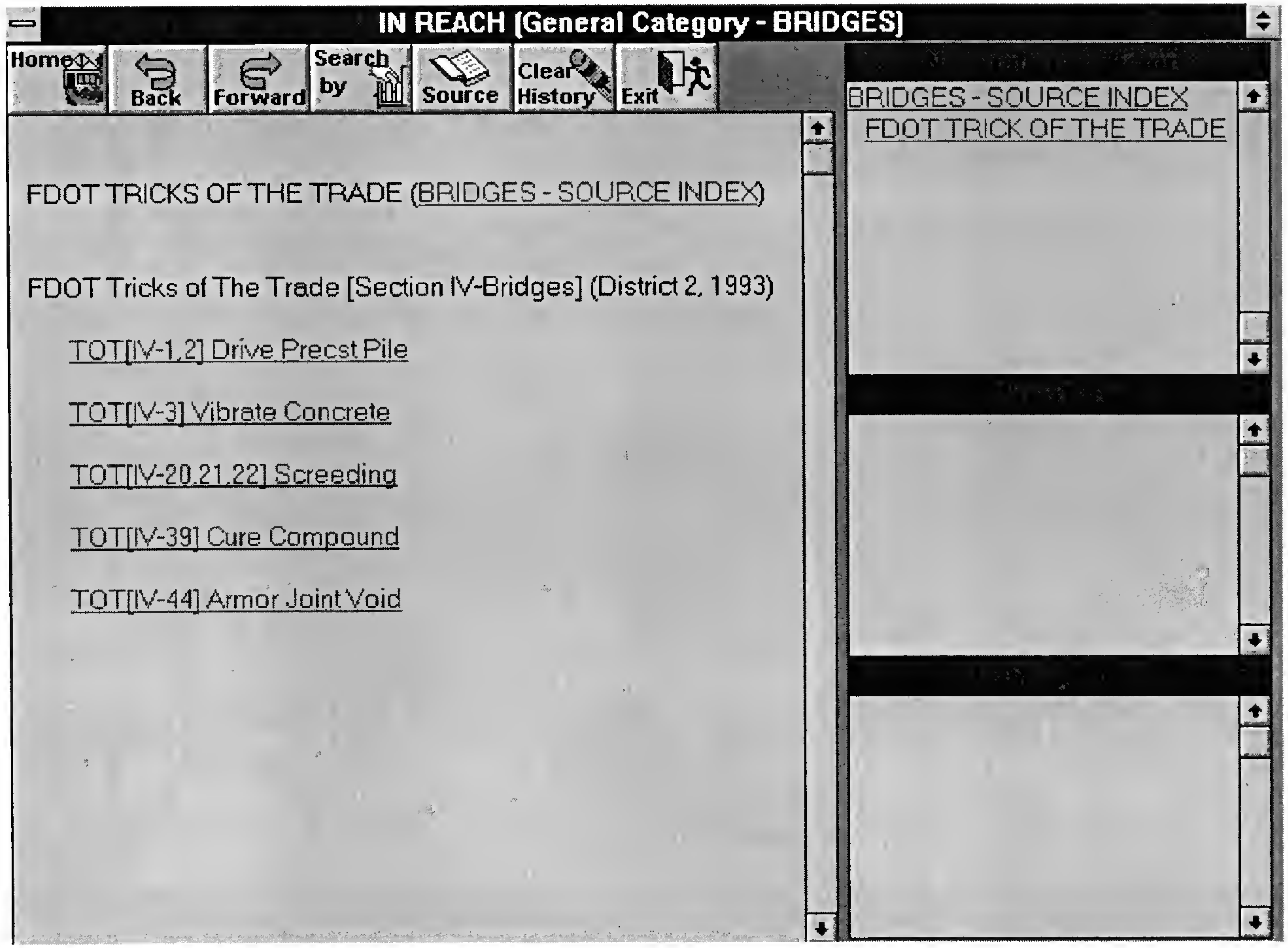


Figure 4.8 - IN REACH FDOT Tricks of the Trade Index Screen for BRIDGES

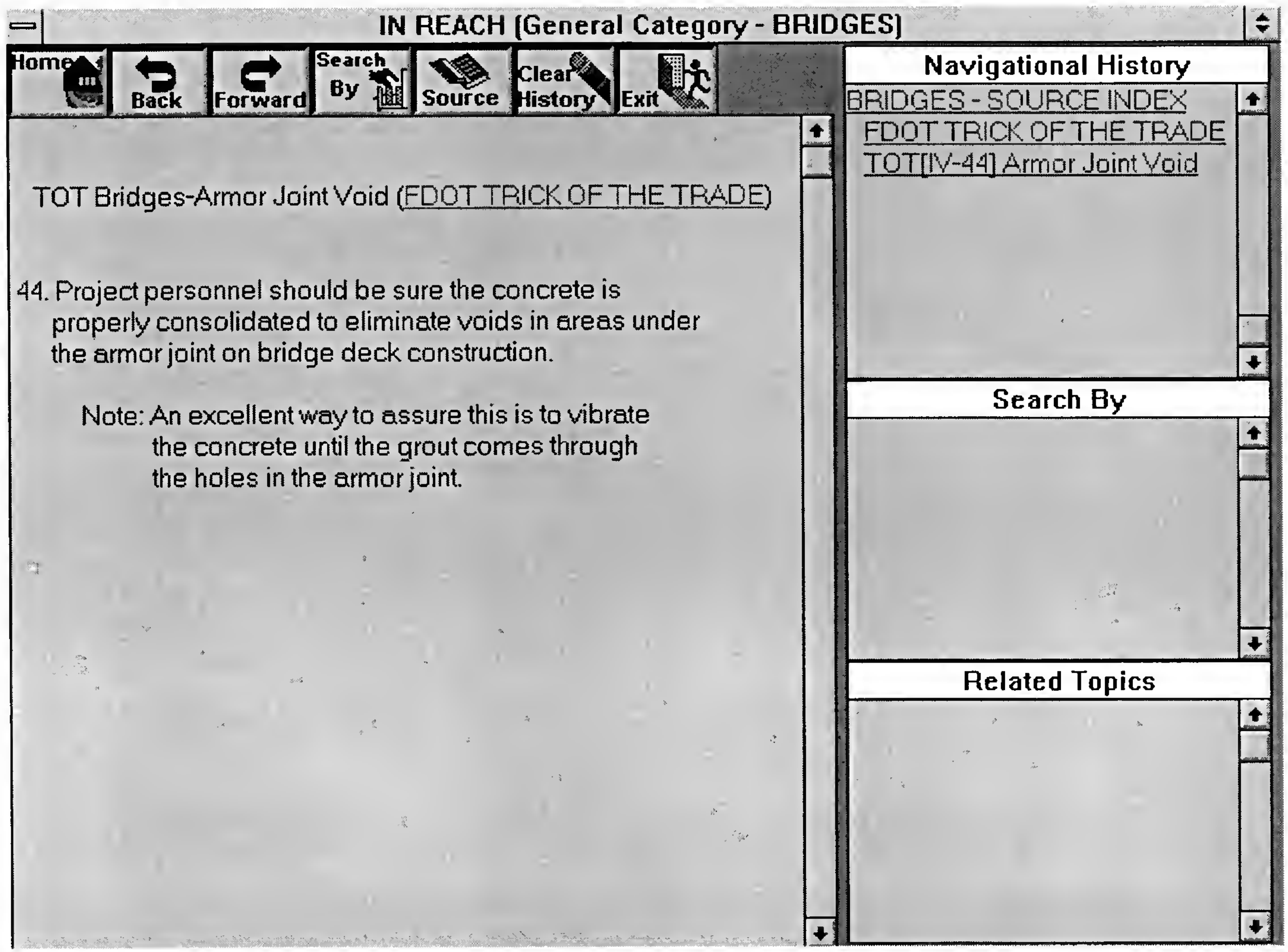


Figure 4.9 - IN REACH FDOT Armor Joint Void Topic Screen for BRIDGES

4.4.2.8 Inspection checklists

Figure 4.10 is the index screen for a collection of inspection checklists currently under development by the FDOT District 2 construction office in Jacksonville, Florida. Given that these documents have not yet been published, coupled with the fact that they represented a significant portion of the overall document base of the IN REACH system, the three checklists, as indexed in Figure 4.10, have been included as Appendix K of this dissertation. Additionally, this screen will be revisited later in the chapter under the discussion of the embedded hierarchal model.

4.4.2.9 CRSI Placing Reinforcing Bars Recommended Practices

Figure 4.11 represents the only document source presented thus far that is not proprietary FDOT published materials. Excerpts from this book, Placing Reinforcing Bars Recommended Practices [Concrete, 1983], were included as part of the IN REACH document base to illustrate the value of other non-FDOT documents. The pages from this industry standard, published by the Concrete Reinforcing Steel Institute (CRSI), represent typical details that any structural inspector should be familiar with. An example of one such informative image can be seen in Figure 4.12, wherein the field ASTM identification markings for typical standard reinforcing bars are pictured. This particular image is linked to the hot key "Illustration-Bar Identification" from the list displayed in Figure 4.11. Again note the convention of IN REACH delineating graphical images by using the word "Illustration."

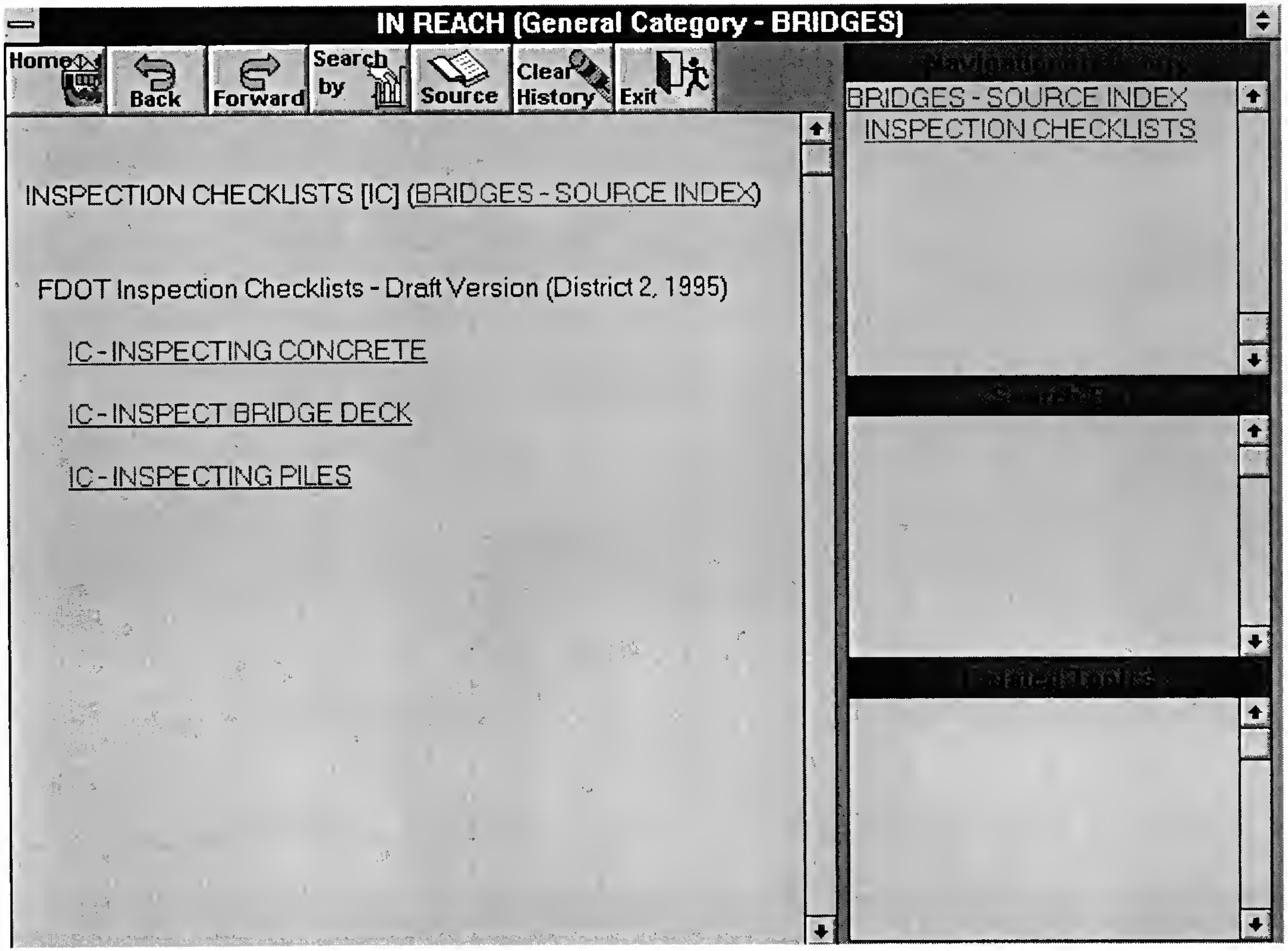


Figure 4.10 - IN REACH FDOT Inspection Checklists Index Screen for BRIDGES

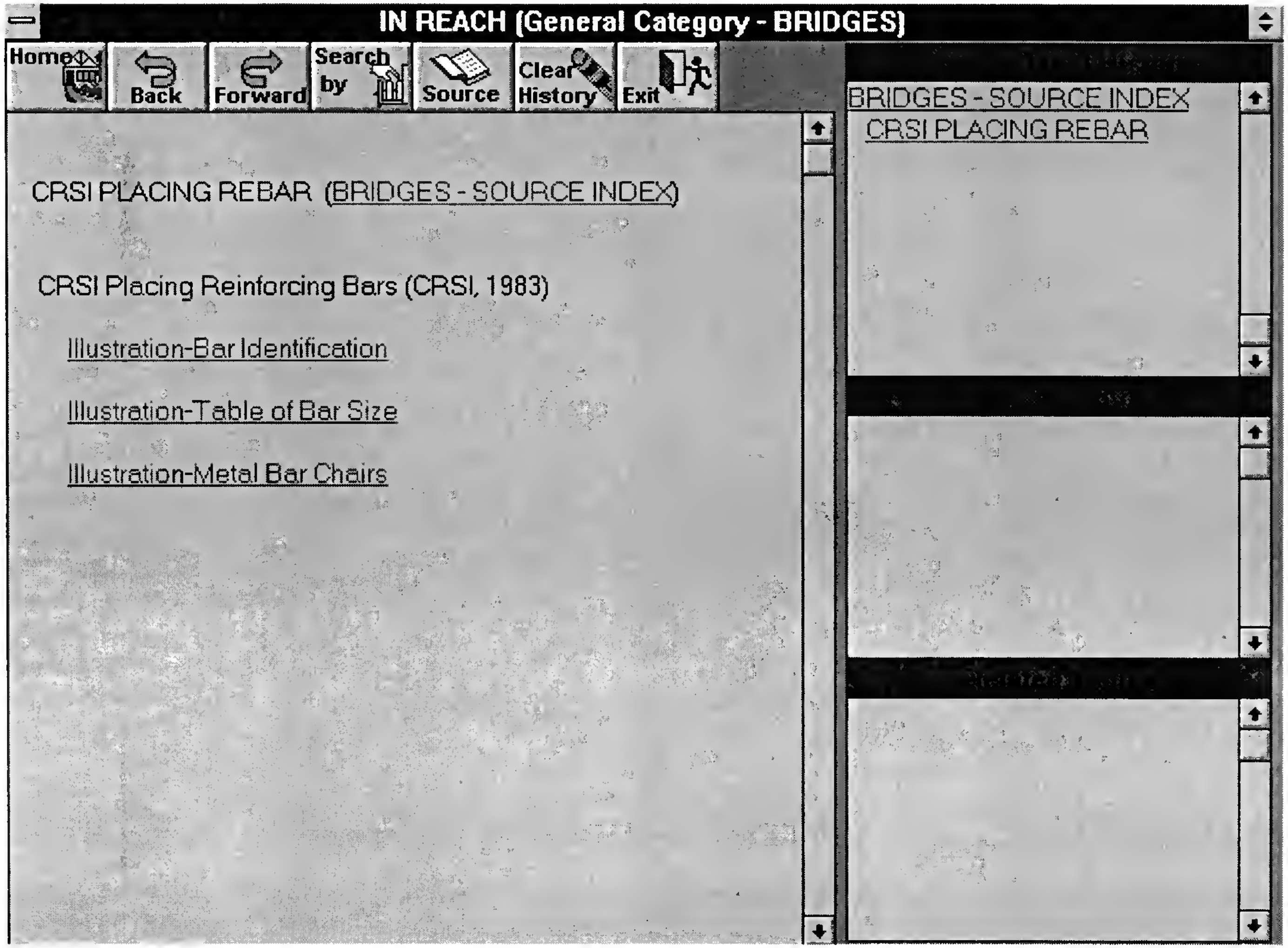


Figure 4.11 - IN REACH CRSI Placing Rebar Index Screen for BRIDGES

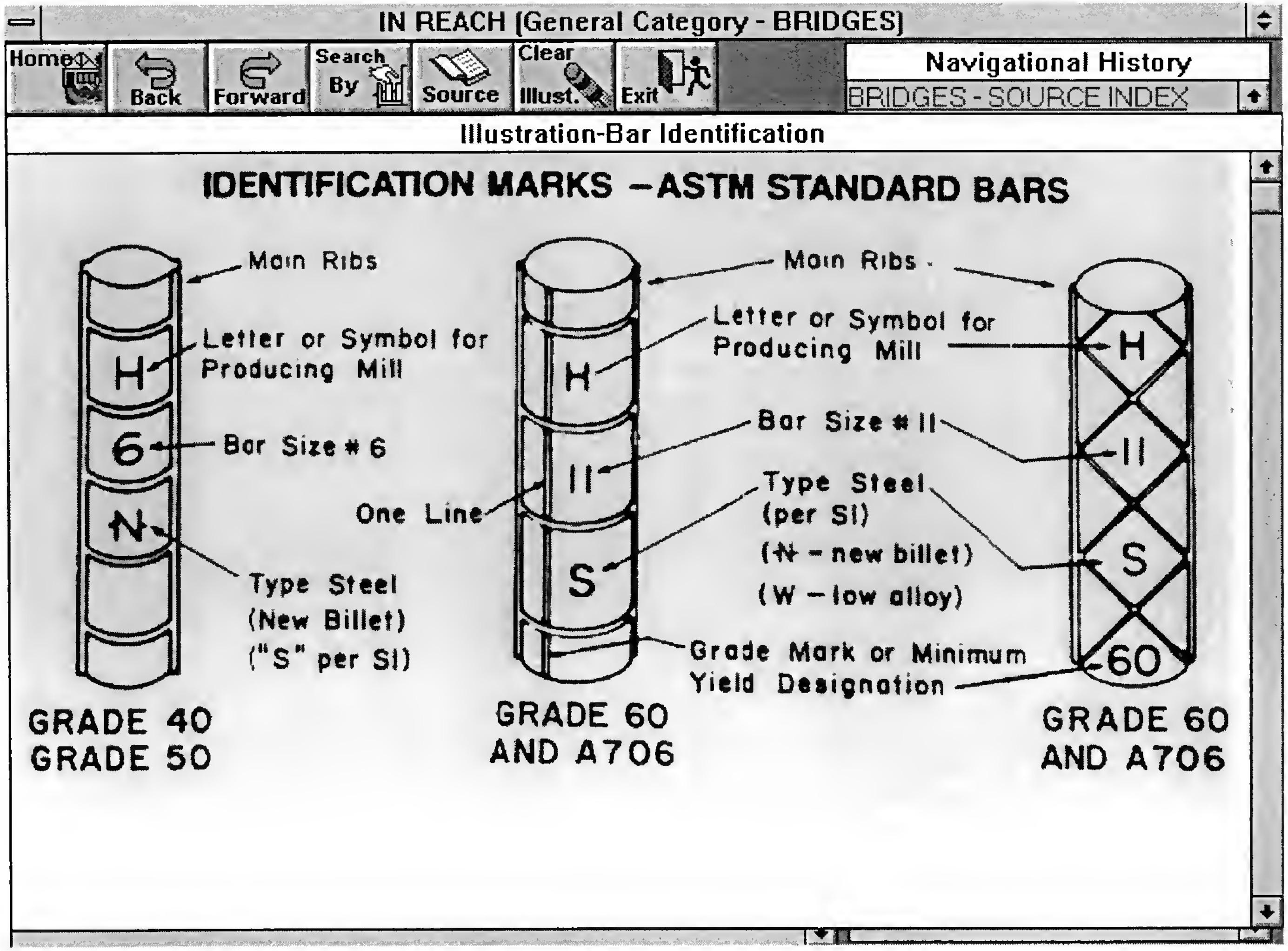


Figure 4.12 - IN REACH CRSI Bar Identification Illustration Screen for BRIDGES

4.5 Lessons Learned from Post Construction Conferences

4.5.1 General Comments

As was stated previously, the method that was proposed for capturing heretofore undocumented construction knowledge and experience, was the establishment of a post construction conferencing program within the FDOT, requiring project teams at the end of a job to generate some type of report detailing the problematic areas encountered during the life of the project. Presented next will be two different sources from which lessons learned were generated for inclusion into the IN REACH knowledge base. The first lessons learned source is represented by Figure 4.13. This program was initiated by the Quality Initiatives Office (QIO) in Tallahassee, and is maintained on the DOTNET, an FDOT network of computers that can be accessed through the Internet given that the user has an authorized code and password. The second source for lessons learned comments is the proposed post construction conferencing program developed under this research endeavor, examples of which are listed on the index screen as illustrated by Figure 4.14. Each of these two lessons learned sources will be covered next, with special attention being paid to the post construction conferencing method of Figure 4.14.

4.5.2 FDOT Process Performance Reviews Lessons Learned

4.5.2.1 General Comments

The Process Performance Reviews (PPR) program was developed in 1991 as a result of a State of Florida Mandate (Procedure Number 455-000-025-b) which read in part [Quality, 1994, p. 3]:

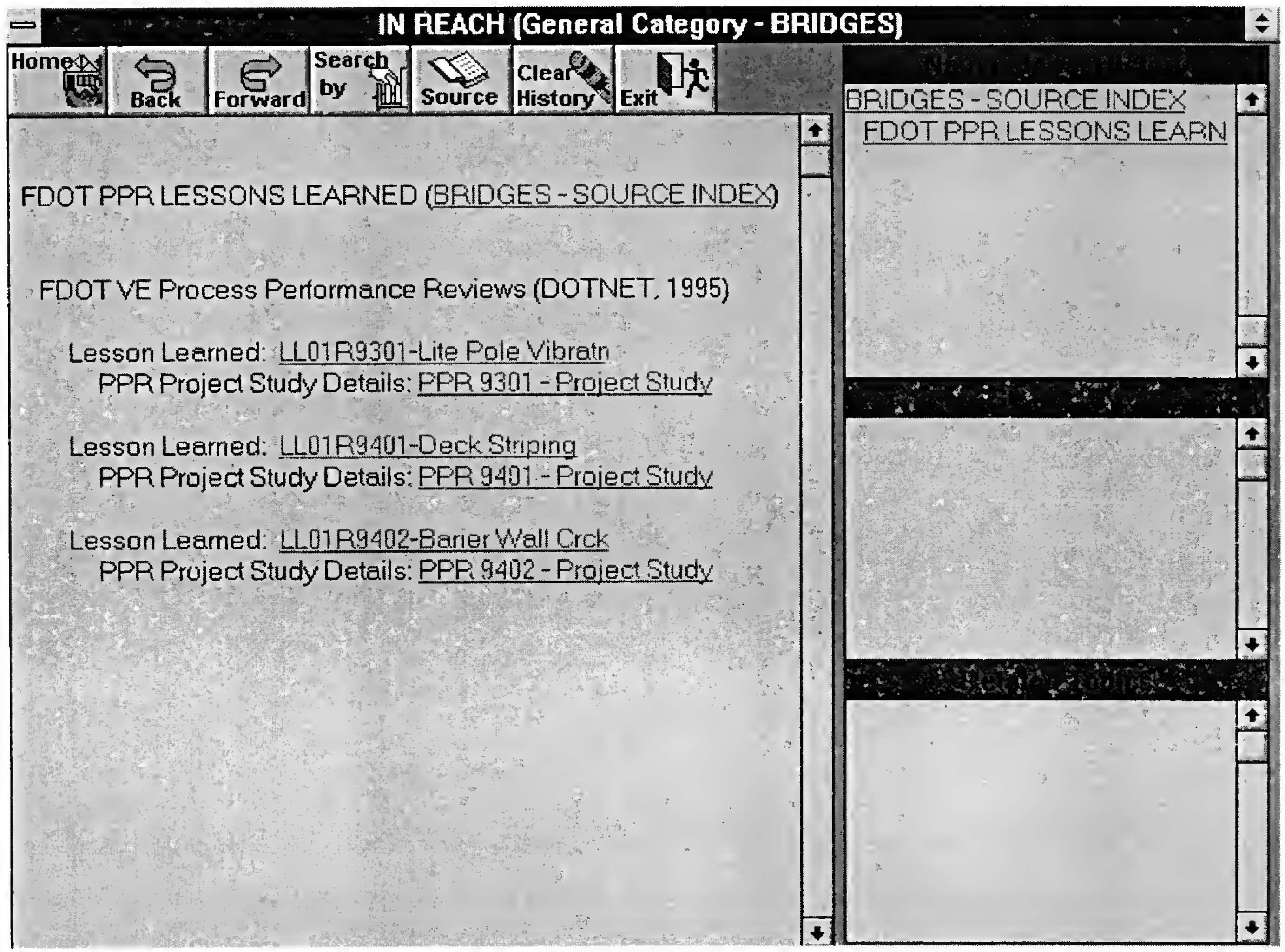


Figure 4.13 - IN REACH FDOT PPR Lessons Learned Index Screen for BRIDGES

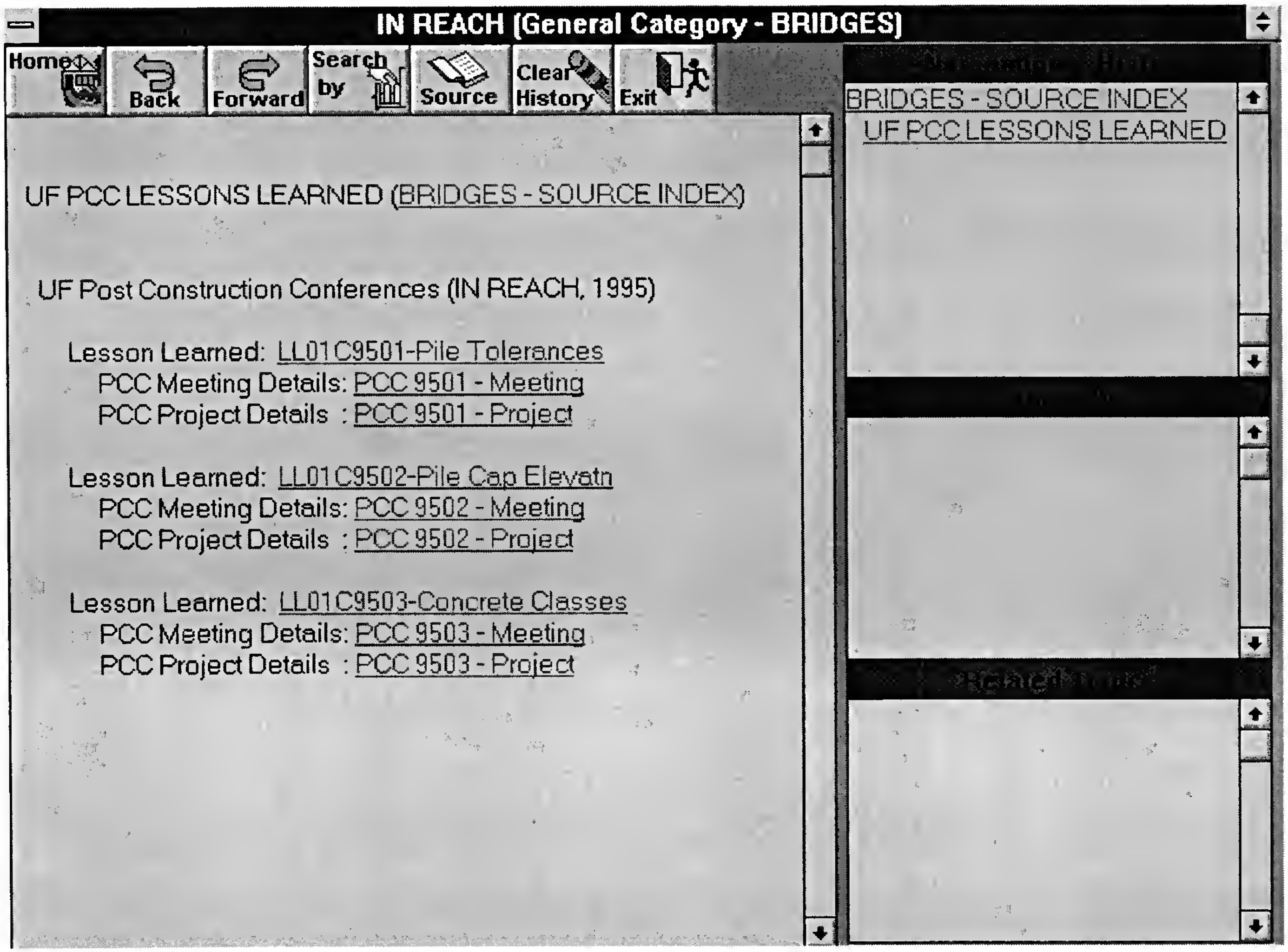


Figure 4.14 - IN REACH UF PCC Lessons Learned Index Screen for BRIDGES

> The intent of the PPR procedure is to assure that Department teams regularly observe samples of completed projects, and through an organized approach systematically develop methods to ensure that all opportunities for improvement are identified and incorporated in future projects.

Although the PPR's are centered around a value engineering perspective and are conducted between one and two years after the project completion date, the conceptual approach that they represent may be modified and implemented in the field of construction operations. Next, one particular comment set will be presented in detail as an example of the type of information available via access to the PPR database.

4.5.2.2 PPR lessons learned comment referencing light pole vibrations

Although a variety of construction related comments were found to exist upon a detailed search of the PPR database, only the three indexed comment sets as listed in Figure 4.13 were selected as representative examples. From this list of three, one has been chosen to be expanded upon herein. Figure 4.15 represents this particular comment garnered from the DOTNET associated with new bridge construction. Notice that the descriptions follow the standard value engineering format of "Problem Statement--Problem Cause." This comment references the condition of excessive vibration of bridge mounted light poles when placed at mid points along typical bridge spans. Although to an experienced field engineer, this may seem rather self evident, most novice practitioners probably would never identify this condition as a potential problem. Figure 4.16, which can be called up by clicking on the hot key of "PPR 9301--Project Study" as shown in Figure 4.15, allows the user access to more detailed information concerning the project study from which this comment was generated.

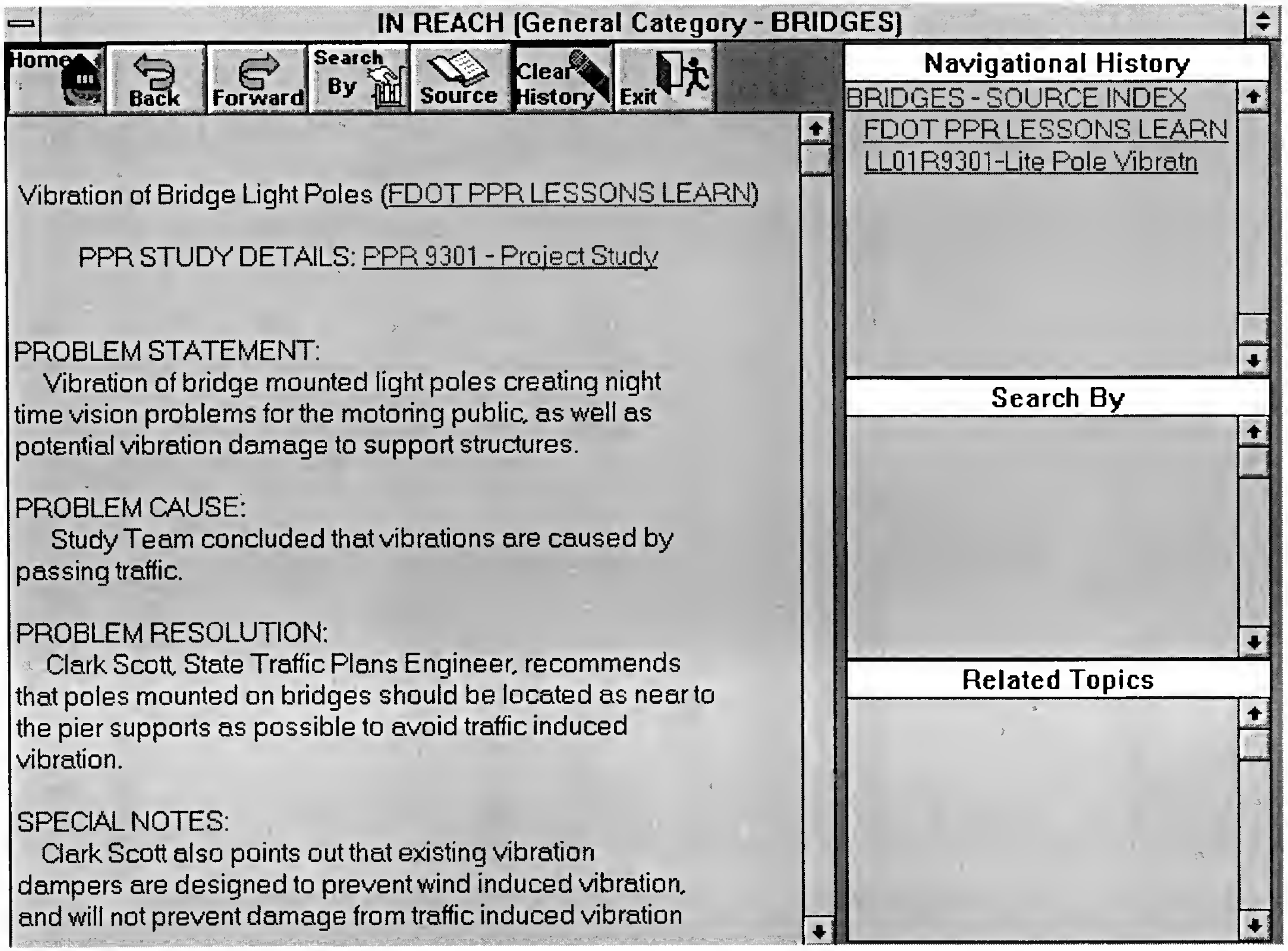


Figure 4.15 - IN REACH Pole Vibration Lesson Learn Topic Screen for BRIDGES

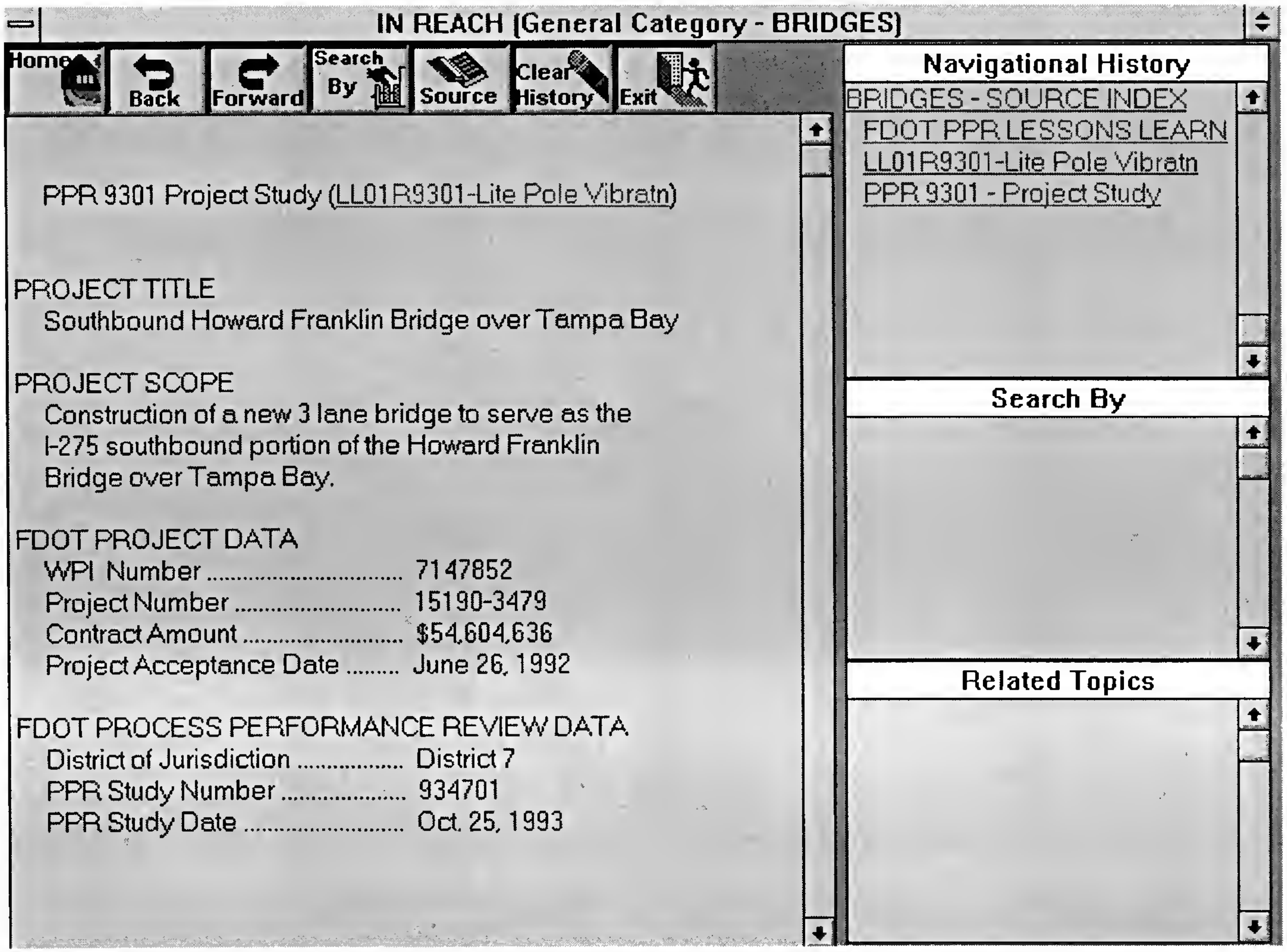


Figure 4.16 - IN REACH Pole Vibration Project Data Topic Screen for BRIDGES

4.5.3 UF Post Construction Conferences Lessons Learned

4.5.3.1 General comments

This section embodies the efforts of this research endeavor with respect to developing a systematic approach for acquiring and capturing heretofore undocumented construction knowledge and expertise. As opposed to the standard interviewing techniques discussed earlier, it was felt that this process could lead to more focused comments that would tend to be less influenced by the personalities of the various participants. Given that IN REACH is admittedly restricted in scope and was developed specifically as a prototype system, only a limited number of experimental post construction conferences (PCC) were conducted. Of these test sessions the three most productive meetings, as illustrated by Figure 4.14, were chosen for inclusion into the IN REACH document base.

The proposed PCC approach would mandate such a meeting be held at the end of every significant project let and constructed under the jurisdiction of the FDOT. Appropriate and worthwhile comments gleaned from these meetings could then be integrated into the existing knowledge base of an IN REACH type system. Even if, for example, only a few useful comments were obtained per project, in a relatively short time the Department could amass several hundred comments, based on the current number of ongoing projects within the state of Florida. As part of the development of the PCC approach, a preliminary form was generated as a means of recording pertinent project and meeting data, as well as providing some guidelines for modeling potential lessons learned comments. Appendix L contains the form utilized during the various post construction conferences conducted as part of this research effort. Presented next will be an example of one particular PCC meeting and the lesson learned comment generated from this meeting.

4.5.3.2 UF PCC lessons learned comment referencing top of pile cap elevations

Figures 4.17a and 4.17b represent an example of a lesson learned comment generated from an experimental PCC conducted at the jobsite of the Vilano Beach Bridge located in Saint Augustine, Florida. These two figures are actually one node that can be viewed in its entirety by manipulating the scroll bar located on the right edge of the window. Figure 4.17a is the view that the user would see when the scroll bar control button is dragged all the way to the top of the scroll bar (note the position of the little square directly under the up arrow of the scroll bar), while Figure 4.17b is the view when the scroll bar button is dragged to the extreme bottom of the scroll bar. The format developed for organizing the lessons learned comments is a variation of that used by the value engineering PPR approach. First a short description of the background of the particular problem is presented, followed by a "Problem Resolution" statement and then any applicable "Special Notes."

Specifically relating to Figures 4.17a and 4.17b, the situation being discussed centers around a design error with respect to the specified pile cap thicknesses and top of cap elevations. This particular bridge, although classified by an inland location, is within one mile of the Saint Augustine inlet, thus subjecting it to coastal tidal variations. Apparently the designers overlooked this fact, and as a result, during extreme high tides, such as those that occur under full moons during the Spring Tide time of year, the pile caps actually become submerged under several inches of water which is an obvious navigational hazard. Although it is not the responsibility of construction personnel to specify pile cap elevations, a conscientious Project Engineer would be wise to verify tidal elevations with the Coast Guard prior to beginning construction, in order to avoid the problems now being experienced at the Vilano Bridge.

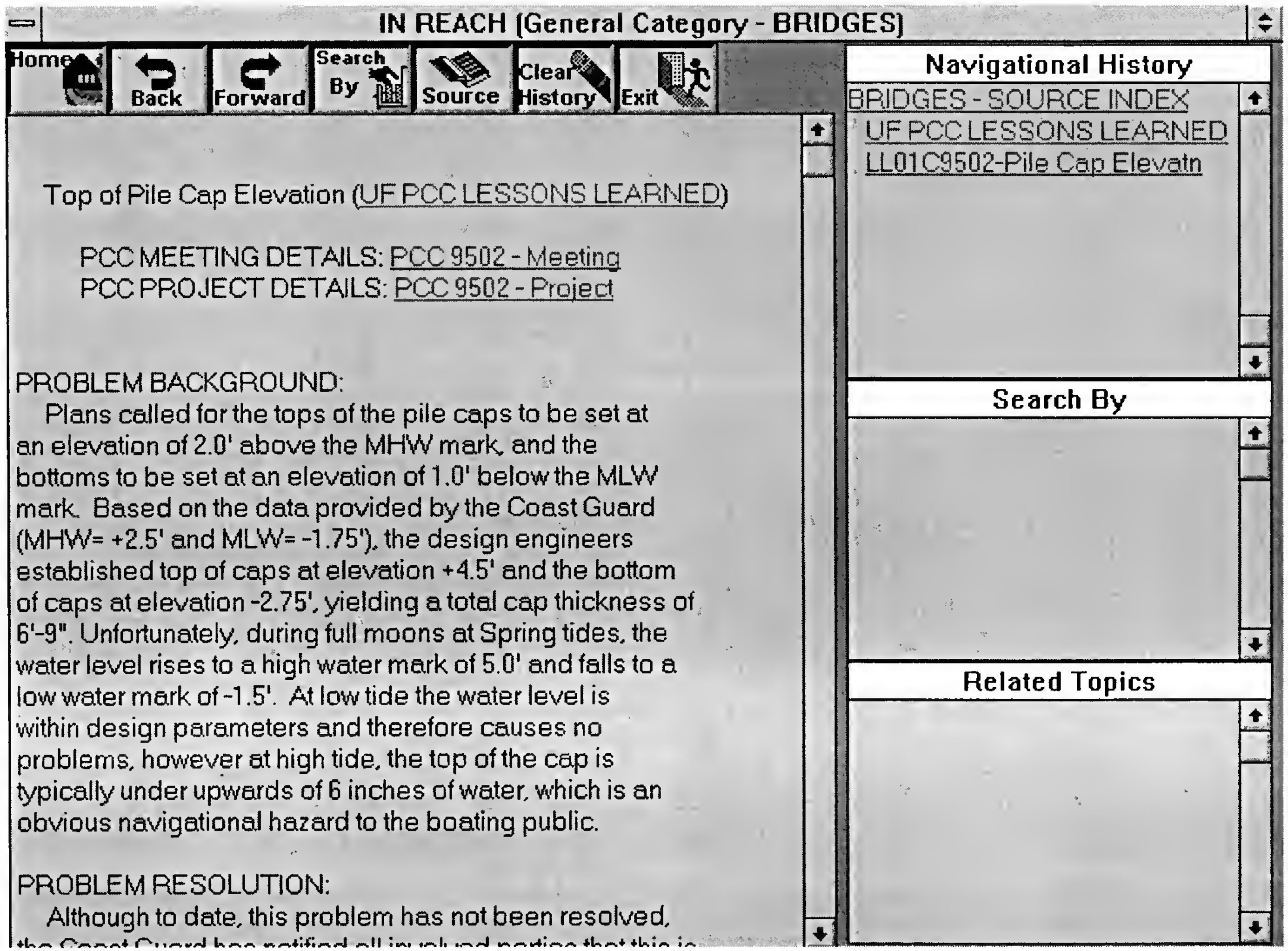


Figure 4.17a - IN REACH Pile Cap Lesson Learn Topic Screen (1/2) for BRIDGES

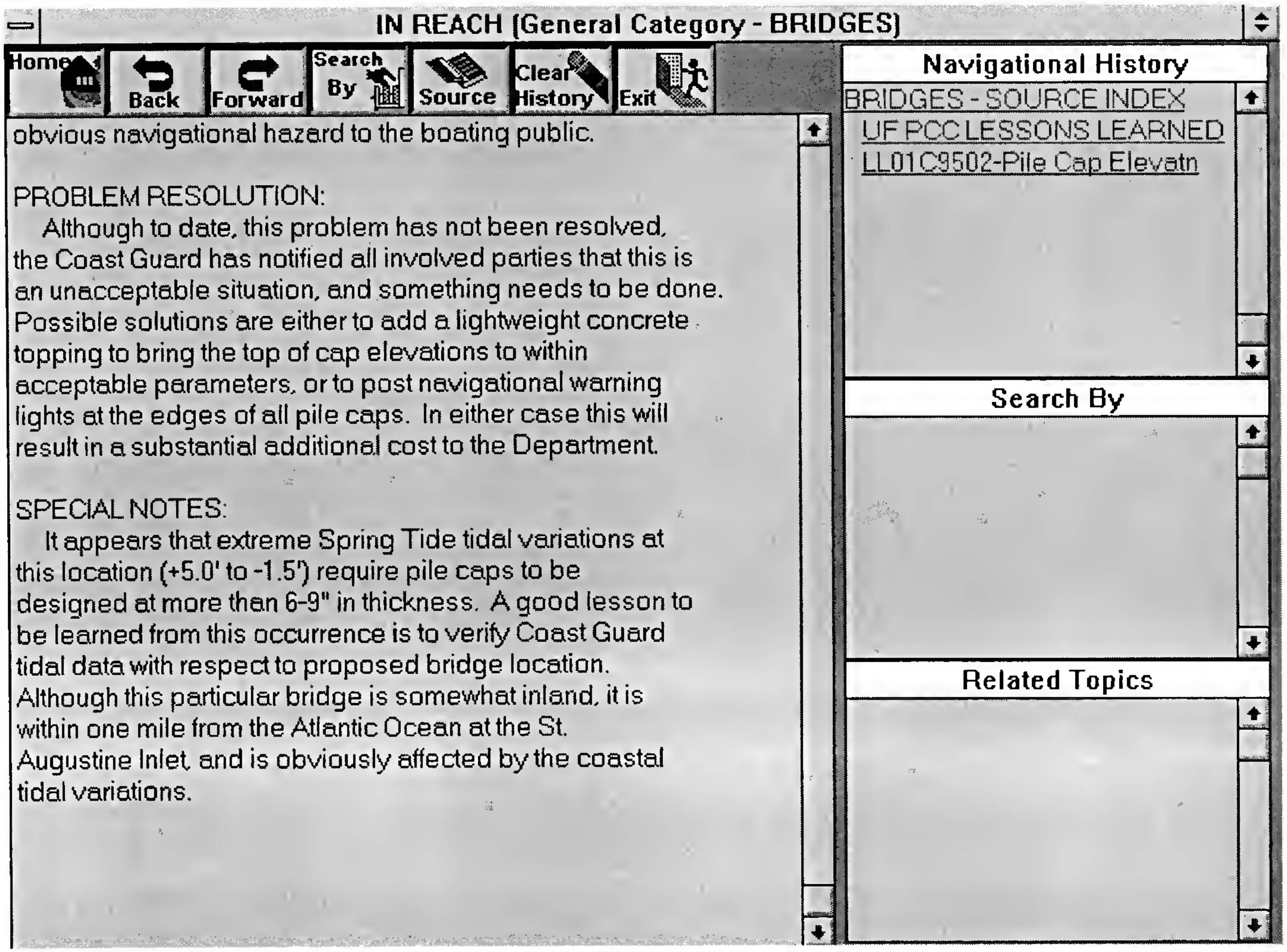


Figure 4.17b - IN REACH Pile Cap Lesson Learn Topic Screen (2/2) for BRIDGES

Finishing up this example, Figure 4.18 contains a variety of information specific to the actual PCC meeting, and can be accessed from the top of the lessons learned node (Figures 4.17a). Figure 4.19, which also can be accessed from Figures 4.17a, as well as from the node represented by Figure 4.18, is a screen from which the user can access vital project specific information, if so desired.

4.6 The Hierarchial Structured Hypertext Network of IN REACH

4.6.1 General Comments

As part of the discussions in Chapter 3 relating to integrating database modeling with hypertext systems, the concept of imbedding a hard-wired, hierarchal structure was presented. The term hard-wired refers to the creation of a hot key string of alphanumeric characters placed within the text of a particular node that is directly linked to another node in the hypertext network. The particulars of creating hot keys utilizing the IN REACH software package (KnowledgePro Windows) will be examined later in Chapter 5. Presented next is a review of the hierarchal structure of IN REACH, augmented by several captured screens from the prototype system.

4.6.2 A Graphical Representation of the Hierarchal Structure

4.6.2.1 General comments

Figure 4.20 depicts the nodal network of the IN REACH prototype system interconnected via the one-to-one, parent-child linkage structure. Although the network contains a myriad of other links, or hot keys, for the purposes of this discussion, only the parent-child linkage structure has been illustrated in this figure. One particular path through

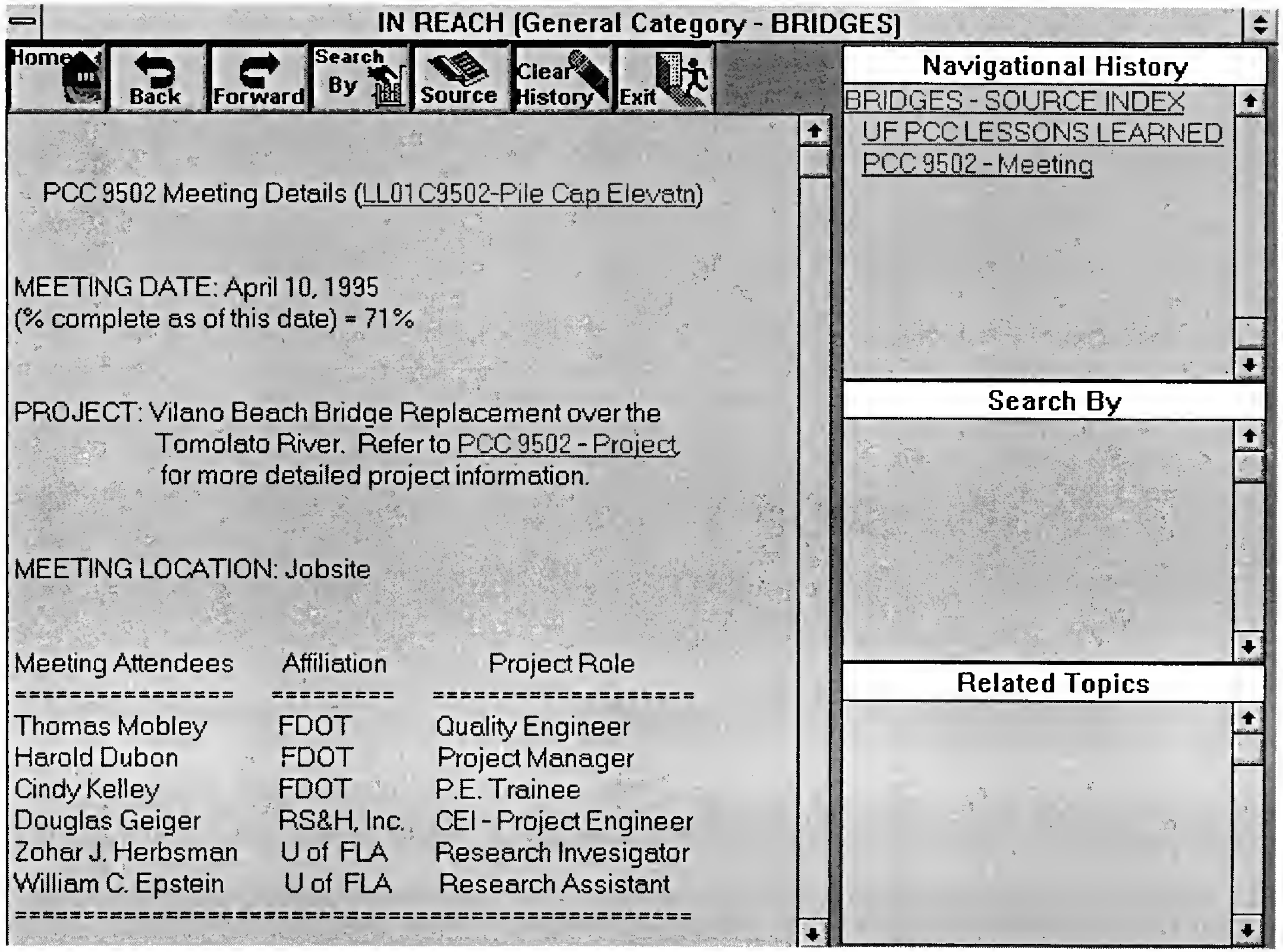


Figure 4.18 - IN REACH Pile Cap Meeting Data Topic Screen for BRIDGES

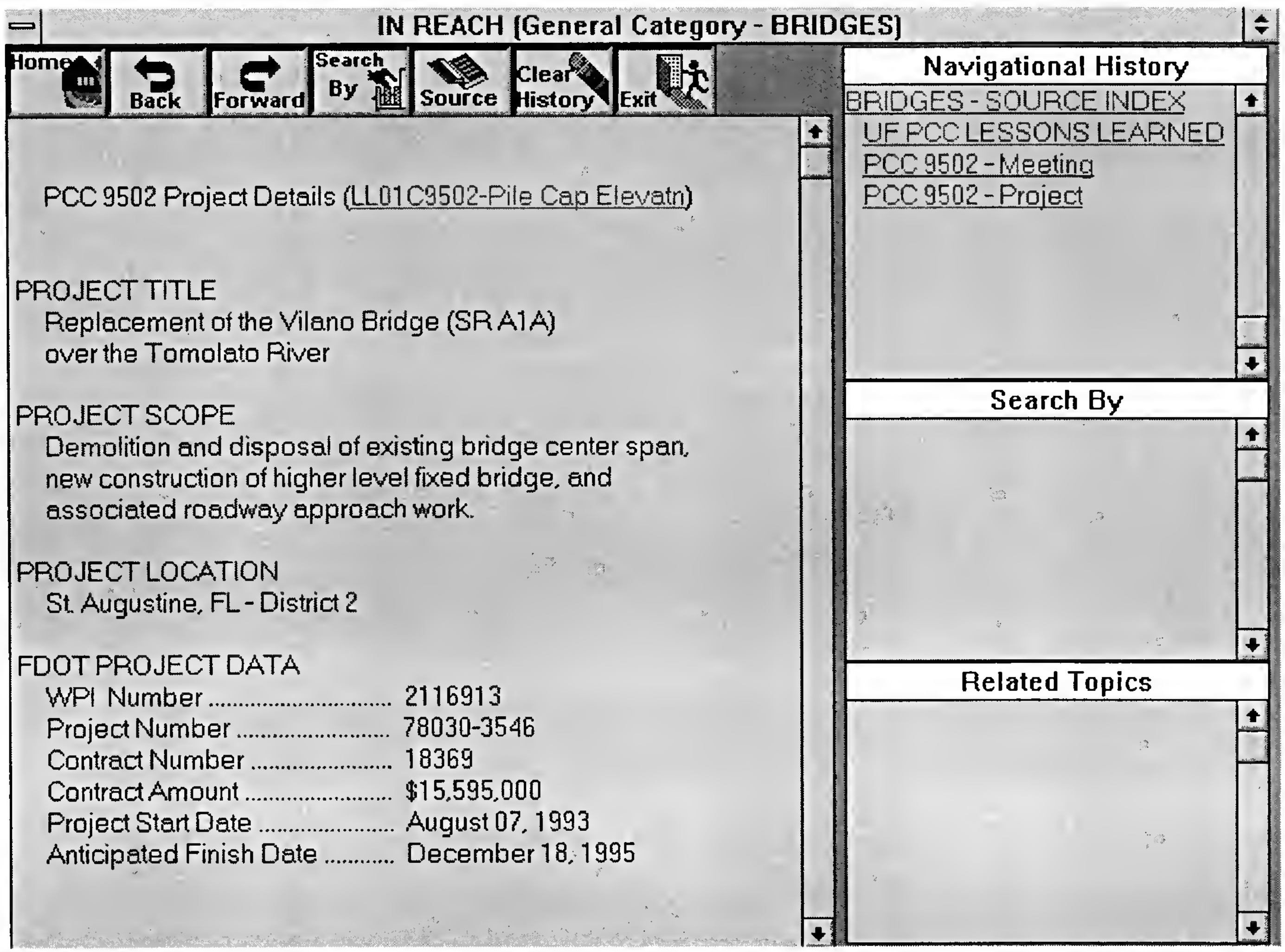


Figure 4.19 - IN REACH Pile Cap Project Data Topic Screen for BRIDGES

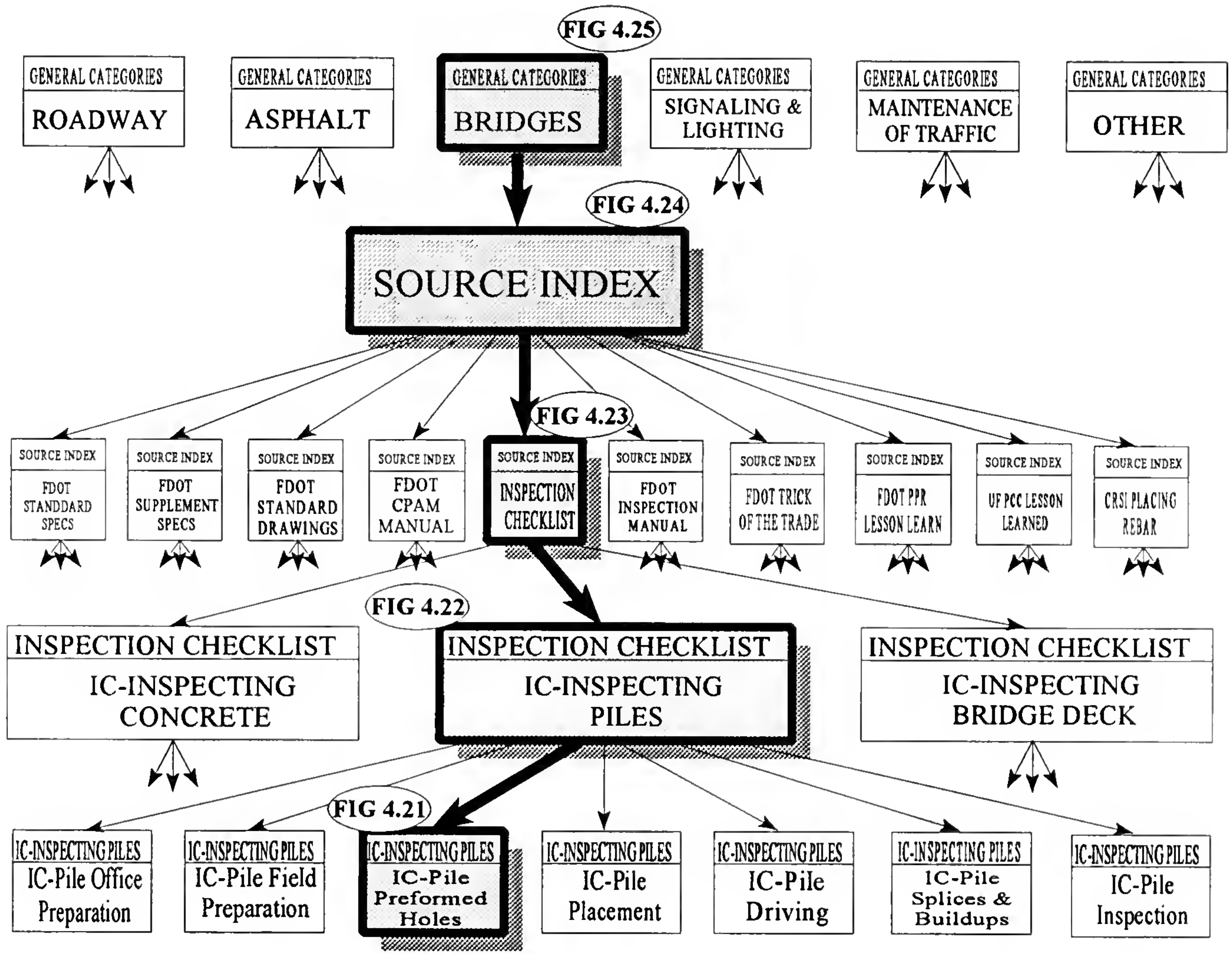


Figure 4.20 - Representation of IN REACH's Embedded Hierarchal Model

the network, represented by the shaded rectangular nodes and the thicker outlines and link arrows, will be followed from the bottom up utilizing the five related screens captured from IN REACH. Furthermore, ellipses containing the corresponding figure numbers have been inserted next to each node that will be illustrated. One additional note with respect to Figure 4.20, is that the arrow head convention of the link lines is arbitrary and was done so only so as to be able to distinguish one end from the other. In other words because of the imbedded parent-child linkage structure, the user has the added option of navigating upwards through the hierarchal tree (arrow head to arrow tail), which supplements the naturally downward navigation (arrow tail to arrow head) driven by the system's use of index type screens.

4.6.2.2 A detailed look via a parent-child path through the IN REACH hypertext network

This example will begin with the shaded node at the bottom of Figure 4.20 having the name "IC-Pile Preformed Holes" ("IC" stands for Inspection Checklist). Given that the system was based on documented information, the hierarchal structure natural followed this model. To illustrate, Figure 4.21 is the captured screen associated with this particular node. Notice that every screen has a title line, in this particular case the title is "Preforming Pile Holes (IC--INSPECTING PILES)." The underlined text contained within the parenthesis, "(IC--INSPECTING PILES)" indicates the parent node of the Figure 4.21 node based on the source document origin. In other words, Figure 4.21 is the child, or the subpart, of the node called "IC--INSPECTING PILES." The user only has to click on this hot to display Figure 4.22, the node called "IC--INSPECTING PILES." Remembering the IN REACH convention of all capital letters signifying an index screen, Figure 4.22 is just such a screen listing the various checklist subparts that are available under the category of inspecting piles.

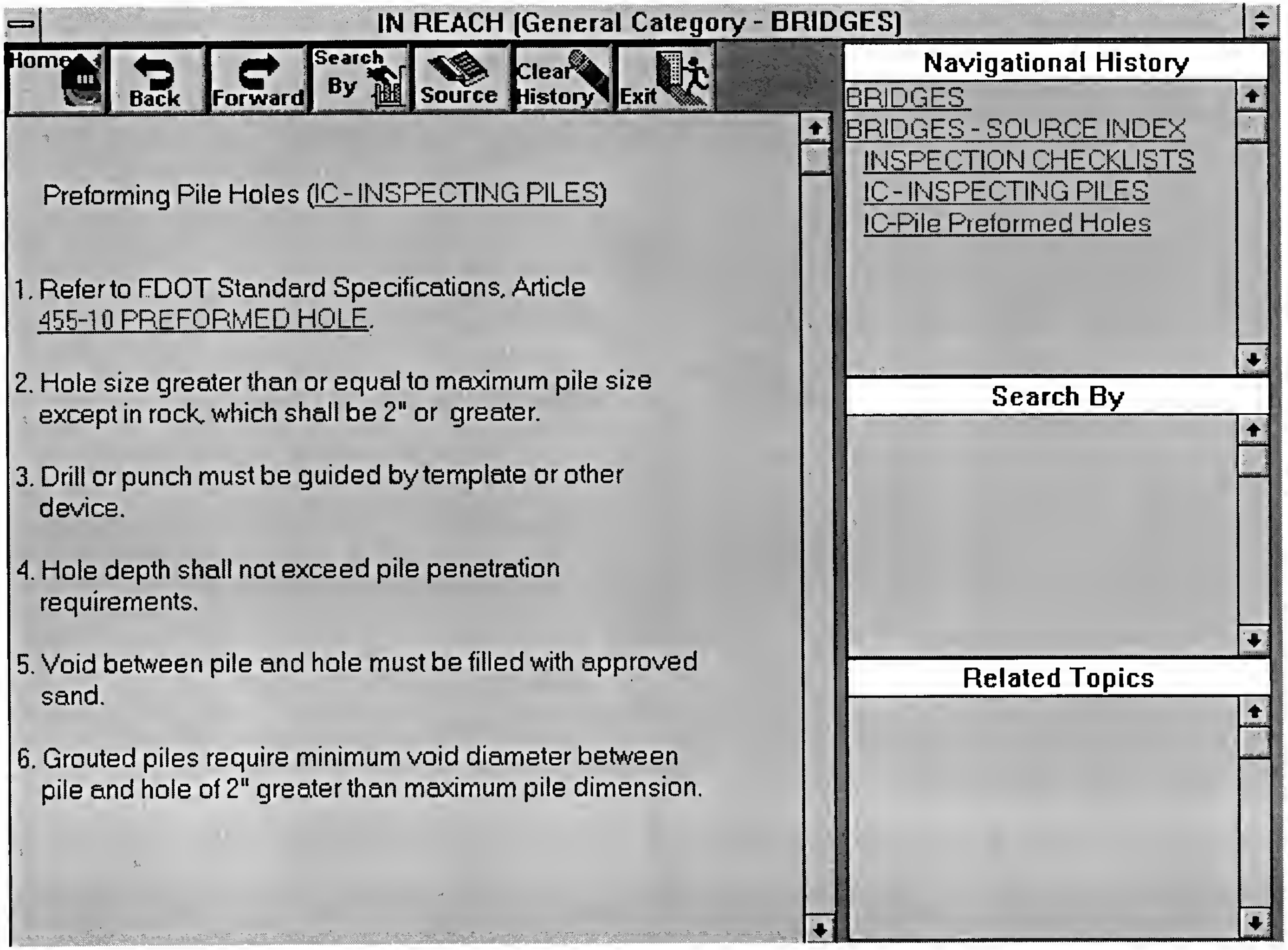


Figure 4.21 - IN REACH IC- Preformed Pile Holes Topic Screen for BRIDGES

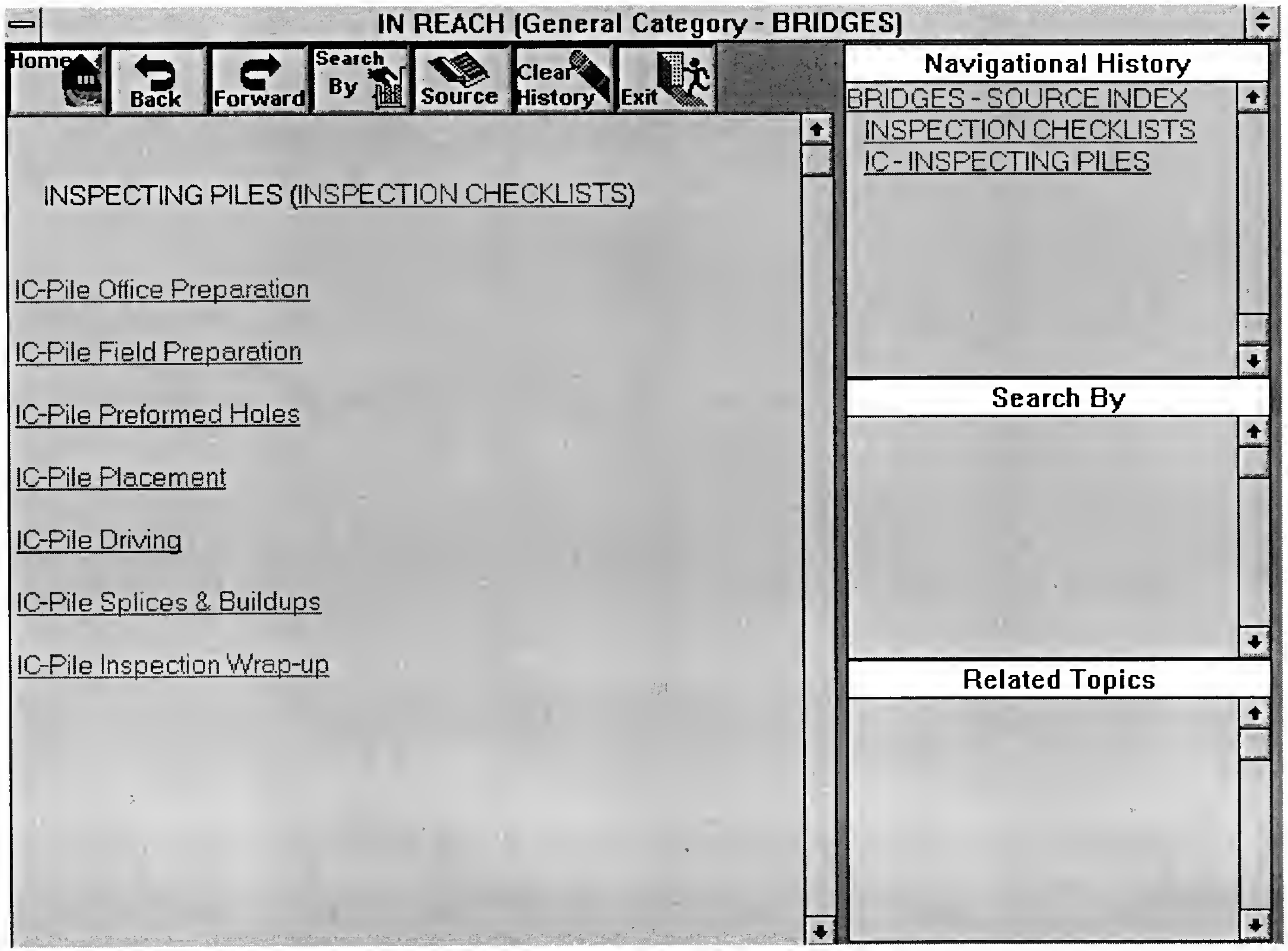


Figure 4.22 - IN REACH FDOT Inspecting Piles Index Screen for BRIDGES

Again just as in Figure 4.21, the node represented in Figure 4.22 also has a parent, namely "(INSPECTION CHECKLISTS)." If the user so desires, he or she can continue navigating up the hierarchal tree towards the origin of the source document by clicking on this hot key which will access this node located one level up, depicted by Figure 4.23, and which was also presented earlier in this chapter as Figure 4.10. Clicking on the parent of this screen "(BRIDGES--SOURCE INDEX)" will display Figure 4.24, which is the same screen as Figure 4.1. Completing this example, if the user clicks on the parent of Figure 4.24, "(BRIDGES)," the node illustrated in Figure 4.25 will pop up for viewing. This node represents the top of the hierarchal tree, and as such is referred to as the "Home" screen, or page, of the general category of BRIDGES. One other note, the image displayed (the Skyway Bridge in Tampa, Florida) as part of this screen has no particular significance, other than the fact that it is one of the premiere bridges in all the world, and a structure that the FDOT should be very proud of.

4.7 Final Comments

This chapter has presented a comprehensive discussion of the strategies and documents utilized in developing the knowledge base of the IN REACH prototype system. As an additional point, and in reference to one of the originally stated research objectives, namely "creating a system that allowed for relatively easy future expansion to the basic system architecture," the modular design of the IN REACH prototype system should be emphasized. Noted several times already, and illustrated during the hierarchal structuring example beginning with Figure 4.20, only the general category of BRIDGES was developed

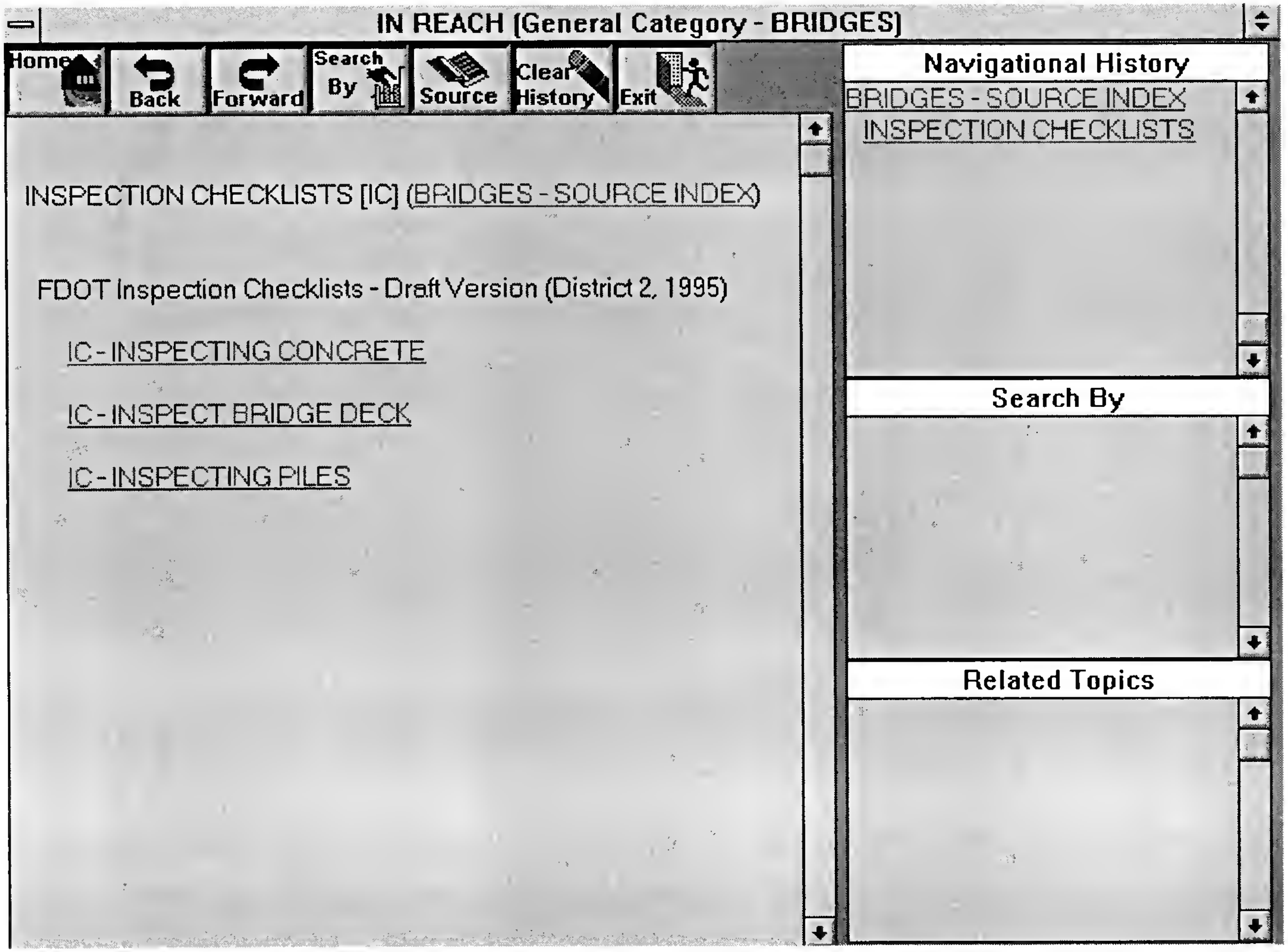


Figure 4.23 - IN REACH FDOT Inspection Checklists Index Screen for BRIDGES

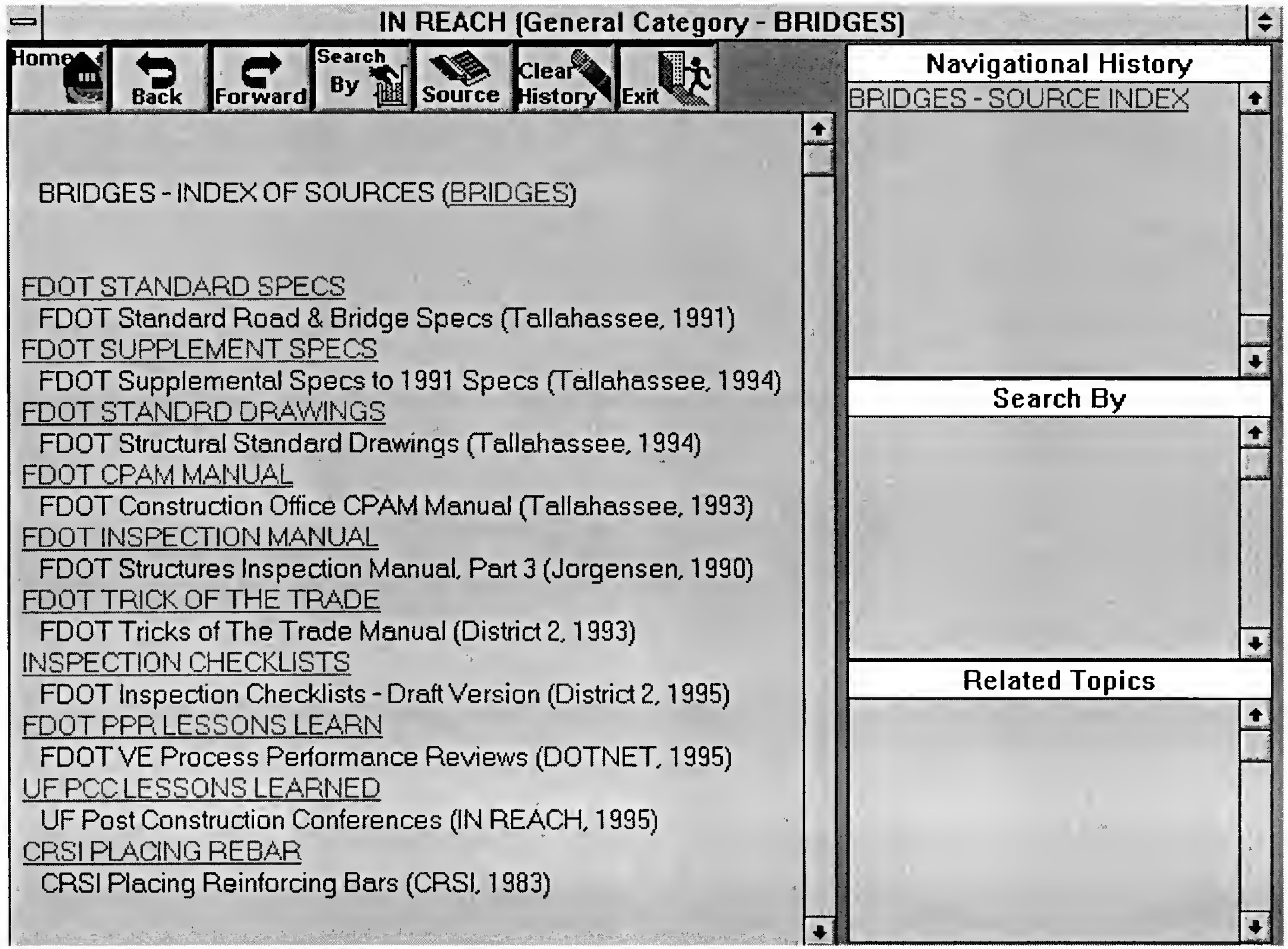


Figure 4.24 - IN REACH Index of Sources Index Screen for BRIDGES

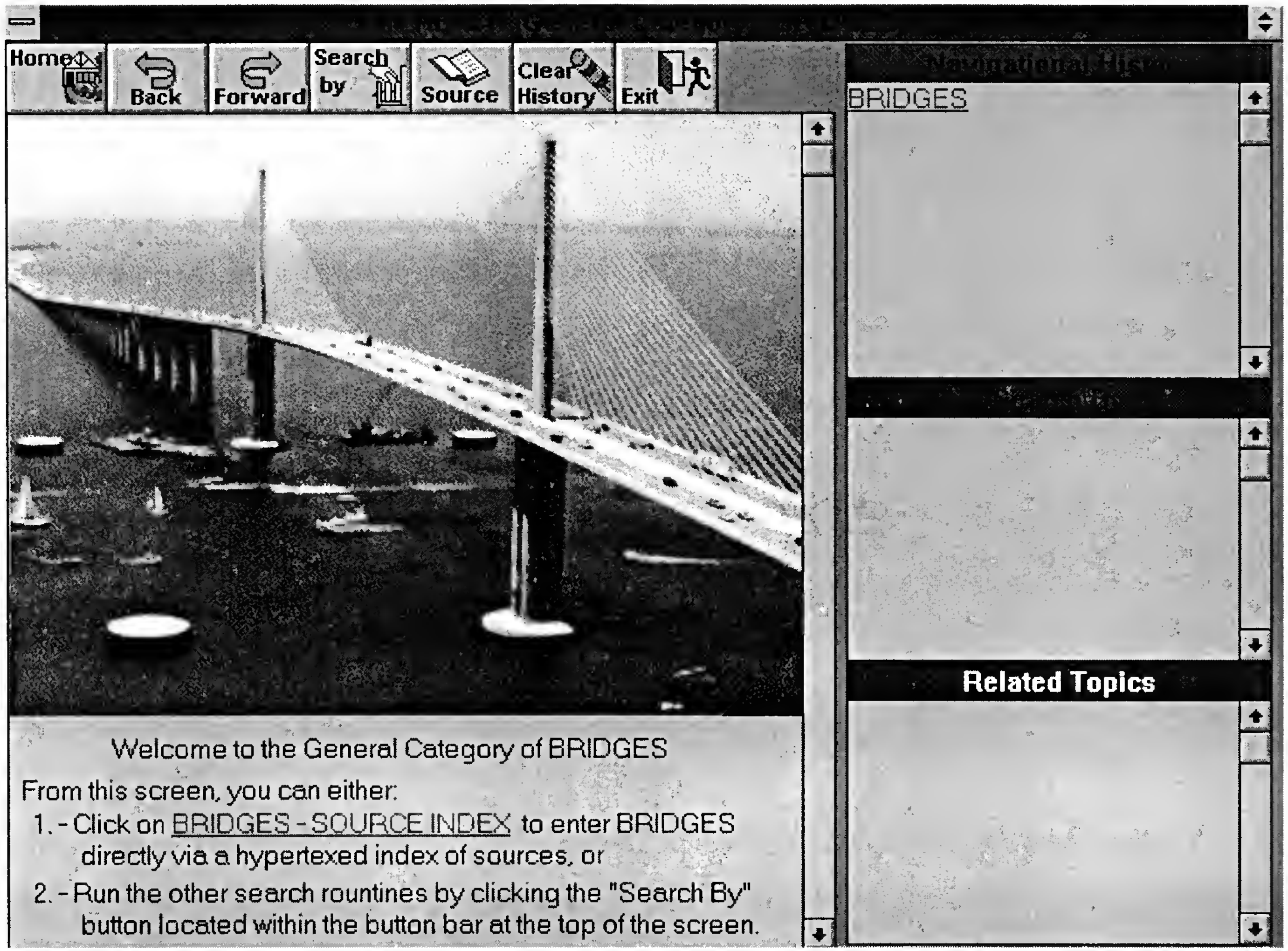


Figure 4.25 - IN REACH Home Screen for General Category of BRIDGES

under this research effort. Thinking of "BRIDGES" as a single module, other modules, such as "ROADWAY" or "ASPHALT," which have already been accounted for, can be developed in the future, and simply plugged into the system in their appropriate locations. Additionally, due to the underlying hypertext format, any hot key text string describing an existing network node can be imbedded in a newly developed node and require no additional programming for direct access to the existing node in question because that existing node has already been associated with that particular hot key elsewhere in the network. Not only is the basic architecture of IN REACH's hypertext network easily expandable, but the modular design of the relational tables utilized for the more advanced searching techniques also will provide for relatively easy future expansion to the system. Particulars of these relational tables, along with the other aspects of the IN REACH developmental system will be fully addressed next in Chapter 5.

CHAPTER 5
DEVELOPMENT OF THE IN REACH PROTOTYPE SYSTEM

5.1 General Comments

As set forth earlier in the research objectives, one of the fundamental goals of this research endeavor was the development of an information and knowledge computer delivery system which would be both intuitive and user-friendly. The underlying hypertext network, as presented in Chapter 4, certainly accomplishes this objective by the way in which it allows the user to navigate naturally and freely through the knowledge base merely by pointing and clicking the mouse. However, the IN REACH prototype system is more than just simple hypertext system, rather IN REACH has been designed as an integrated environment which utilizes various database management and expert systems strategies as a means of supplementing the basic hypertext network in order to provide a set of structured searching capabilities.

Although these searching routines incorporate rather complicated programming techniques, in keeping with the stated objectives, the interface with the user was required to maintain a friendly appearance. Given that the targeted audience for IN REACH was FDOT construction personnel, many of whom posses only a limited knowledge of computers, the concept of creating a user-friendly environment was even that much more critical, if the prototype system was to be successful. With this in mind, the IN REACH environment was

constructed, always with the needs and requirements of the end-user at the forefront of the developmental strategies. This chapter will present an overview of the prototype system, concentrating on some of the technical aspects of the programming language, as well as attempting to demonstrate the look and feel of IN REACH by capturing a variety of computer screens, similar to the approach taken in Chapter 4.

5.2 A General Overview of KnowledgePro Windows

KnowledgePro Windows (KPWin) is a Windows development tool distributed by a company called Knowledge Garden Inc. located in Setauket, New York. KPWin was introduced to the marketplace in May of 1990, and since that time, a number of prominent organizations, such as Avis, Hewlett Packard, and the United States Department of Agriculture, have incorporated into their daily operations, systems developed under the KPWin environment. KPWin seamlessly integrates a number of cutting edge computer technologies, such as object-oriented programing (OOP), expert systems, and hypertext, all within one visual programming environment. The backbone of the KPWin developmental tool is its proprietary, high-level, event driven language, appropriately enough called the KnowledgePro Language. The strength of the KnowledgePro Language lies in not only its flexibility, but also the significant power derived from its embedded OOP features, such as multiple inheritance [Shaw, 1992; Knowledge, 1994a].

One point of interest that should be emphasized at this time is KPWin's usage of the expression "topic." Although, throughout this dissertation the word topic has been, and will be, used from time to time in describing the chunked information contained within a

particular node of the hypertext network, this term in the KnowledgePro Language has its own specialized meaning. Shaw [1992] calls the "topic" the building block of the KnowledgePro Language, having similar attributes to a "function" or "procedure" in C++ or Pascal. The KnowledgePro user manual [Knowledge, 1991] suggests that the "topic model" was created as a means of overcoming the inflexibility of the expert systems shells, while at the same time adding structure and intelligence to the "informational spaghetti" problem often associated with pure hypertext systems.

Another important feature of the KPWin package is the embedded C++ code generator called KPWin++. The importance of this feature, is that it allows the developer to write his or her entire program using the high-level KnowledgePro Language, which is relatively easy to learn, and then compile this finished application by means of an external C++ compiler, such as Microsoft Visual C++ or Borland C++, to create a generic, industry standard executable (.EXE) file which can then be run on any IBM compatible computer that is running under the Windows operating system. This ability to create a self-contained executable file was critical for this research effort, given the unsupervised prototype testing that was to be conducted, details of which will be presented towards the end of this chapter.

5.3 Some Programming Details About Browsing and Searching

5.3.1 General Comments

The IN REACH prototype system provides two basic categories of information retrieval, one which is a free form of browsing, or navigating, and the other incorporates more structured methods of searching strategies. The browsing capabilities of the IN

REACH system are supported by the underlying hypertext network, which allows for navigation through the knowledge base by clicking on various hot keys depending on personal interest. The second category involves more advanced searching techniques which enable a user to query the system in an attempt locate himself or herself in the "neighborhood" of where that user wants to be, and then continue to browse from that point forward. These more advanced features utilize a combination of relational database techniques, SQL query statements, and expert systems inference strategies as a means of accomplishing the searching routines. Presented next will be a more detailed discussion of each of these general categories as they relate to the IN REACH prototype system.

5.3.2 Developing the Browsing Capabilities of IN REACH

In the KnowledgePro Language, any string of text displayed in a window can be defined as a hot key by simply placing the character set "#m" immediately to the left and immediately to the right of that particular string of text. For example, the word *hypertext* can be made into a hot key as follows: #m*hypertext*#m. As was noted earlier, hot keys are typically displayed in a different color (green and underlined in the case of IN REACH), so as to provide the user with a visual indication that there is more information (another separate node) associated with this particular string of text.

From a programming perspective, when the user clicks on a hot key, IN REACH attempts to call the special topic "mark," which is actually an imbedded routine. This routine searches the hypertext network looking for the node whose stored name exactly matches this particular hot key, and then if found, displays this new node for viewing. The topic "mark" is also used by IN REACH to create an array, or list, which chronologically stores the text

strings of every node visited by the user during a particular session. This array called "ANTES," in terms of the IN REACH program code, a copy of which is included in its entirety as Appendix M of this dissertation, is used for three of the system's basic navigational aids, namely the "Navigational History" window, the "Forward" navigational button, and the "Back" navigational button. These features, along with the other user oriented aspects of the system, will be addressed later in this chapter during the presentation of a guided tour of the IN REACH prototype system.

5.3.3 The Windows Resource Archive Program

Referring back for a moment to the discussion of hot keys, their importance to the hypertext network can not be overemphasized. The strings of text marked as hot keys are actually exact character-by-character matches of a named file which contains the chunked information viewed as an individual node by the user. Given that the functionality of the network depends on the integrity of these imbedded hot keys, as well as the nodal information itself, the makers of KPWin provide an add-on program called WRAP (Windows Resource Archive Program), which in effect "wraps" these files up and archives them in a separate compressed file which can not be accessed by the user. What this does in essence is to create a "read only" environment under which the user can not accidentally modify a hot key, thereby making it unrecognizable to the system.

WRAP is a Dynamic Link Library (DLL) which enables the developer to provide a method of data compression, file security, and structural organization to his or her Windows developmental strategy. According to the WRAP user manual [Knowledge, 1994b], WRAP is based on a high performance data compression algorithm that has the capability of

combining bitmaps, cursors, icons, binary files, and text files all together in a secured resource archive for easy access from within any KPWin application. Depending on the needs of a particular application, WRAP can be optimized for maximum compression or maximum speed. The greater the level of compression, the longer it takes to handle the wrapped file, while on the other hand, one can speed up the process by reducing the amount of compression. For the purposes of the IN REACH prototype, considering the limited knowledge base, the system was therefore optimized for speed.

Under the IN REACH strategy, the creation of the resource file was accomplished by using the WRAP utility which is called Wrapper. This utility allows the developer to create new archives and modify existing ones. Wrapper can either be built directly into the application, or utilized externally, the latter being the case with the development of IN REACH. As was noted, by wrapping the various information files (nodes), the integrity of the system is maintained, and the operations associated with the topic "mark" are protected from user manipulation. The inclusion of the WRAP commands can be seen within the program code as listed in Appendix M.

5.3.4 Developing the Searching Capabilities of IN REACH

5.3.4.1 General comments

Although the browsing capability of hypertext is the underlying concept upon which IN REACH has been designed, the system also supports more direct methods of searching for information. As has been previously mentioned, properties of both the technologies of database management systems and expert systems have been incorporated into the overall programming strategy in an effort to add a sense of structure to the inherently unstructured

environment of a pure hypertext system. Presented next will be further discussion with respect to some of the programming strategies developed for integrating the functionality of both database management systems and expert systems as a means of supplementing the basic hypertext network.

5.3.4.2 Relational database management programming strategies

One of the fundamental developmental approaches utilized by IN REACH was to conceptually classify every node in the hypertext network in terms of a set of predefined subject headings. Upon completion of this task, each node was then stored in one of three relational subcategory tables (databases) as an individual and unique record. Figure 5.1 is an example of one such relational database for the subcategory of "Bridge Deck." Examination of this table indicates that the labels for the subject headings are single letter entries. These letters are actually representative of the corresponding predefined subject headings for the subcategory of "Bridge Deck" as shown in Figure 5.2. For the purposes of differentiating between these two types of IN REACH relational tables, further discussions will refer to the class of tables illustrated by Figure 5.1 as "classification" tables or databases, while those represented by Figure 5.2 will be referred to as the corresponding "configuration" tables. The reason for codifying the subject heading fields of the "classification" tables was strictly for efficiency purposes. In other words, as an example from Figure 5.1 and Figure 5.2, rather than requiring the system to continually search for the field entry of "Materials and Accessories," the utilization of the "configuration" table strategy reduces this relatively long string to a single character, the letter "J" in this case.

Another point to be made with respect to "classification" tables (Figure 5.1), is the labels associated with the fields that appear under the title "SOURCES" (the last ten columns

BRIDGE DECK CLASSIFICATION DATABASE																												
SUBCATEGORY - Bridge Deck		SUBJECT HEADINGS																	SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	O	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	400-5.7 SIP METAL FORMS							T		T			T					T	T									
2	400-5.7.1 general							T		T			T					T	T									
3	400-5.7.2 materiels							T		T	T		T						T									
4	400-5.7.3 design							T		T			T					T	T									
5	400-5.7.4 construction							T		T			T					T	T									
6	400-5.7.5 placing concrete	T						T		T		T	T						T									
7	400-5.7.6 inspection							T		T			T			T			T									
8	400-5.8 SIP CONC FORMS							T		T		T						T	T									
9	400-5.8.1 general							T		T		T						T	T									
10	400-5.8.2 materials							T		T	T	T							T									
11	400-5.8.3 design							T		T		T						T	T									
12	400-5.8.4 construction							T		T		T						T	T									
13	400-5.8.5 placing concrete	T						T		T		T							T									
14	400-5.8.6 inspection							T		T		T				T			T									
16	400-7.15 BRIDGE FLOORS	T										T		T				T	T									
17	400-7.15.1 bulkhead/screed	T									T	T		T				T	T									
18	400-7.15.2 design of screed	T				T						T		T				T	T									
19	400-7.15.3 screeding	T										T		T				T	T									
20	400-9.7 Concrete Deck Joint																T		T									
21	400-15.2.5 class 4 finish			T	T							T		T	T			T	T									
22	400-15.2.8 bridge sidewalks			T	T							T					T		T									
23	400-16.2 Cure Bridge Decks		T									T							T									
24	400-17.2 Deck Mtrl Storage		T								T	T							T									
25	415-5.10 Deck Slabs	T					T				T							T	T									
26	415-5.13 Chairs & Bolsters	T					T	T			T								T									
27	710-6.2 Weather Limitations				T						T								T									
28	710-6.3 Surface Preparation				T						T								T									
29	711-1 Description				T						T								T									
30	711-2.2 Sealing Primer				T						T								T									
31	711-4.2 Apply Seal Primer				T	T					T								T									
32	925-2 Membrane Curing		T		T						T	T							T									
33	IC - INSPECT BRIDGE DECK															T					T							
34	IC-Bridge Deck Curing		T								T	T				T					T							
35	IC-Bridge Deck Dry Screed	T					T					T		T		T		T			T							
36	IC-Bridge Deck Form Remvl							T	T							T					T							
37	IC-Bridge Deck Forming							T	T	T						T		T			T							
38	IC-Bridge Deck General Prep															T		T			T							
39	IC-Bridge Deck Grooving			T								T		T	T	T					T							
40	IC-Bridge Deck Place Concrt	T										T				T	T	T			1							
41	IC-Bridge Deck Place Rebar	T					T				T					T					T							
42	IC-Bridge Deck Screed/Finsh	T		T		T						T		T		T					T							
43	CPAM 9-3 Deck Thickness	T					T					T				T		T					T					
44	TOT[IV-20,21,22] Screeding	T		T		T						T		T		T						T						
45	TOT[IV-39] Cure Compound		T		T						T	T				T						T						
46	TOT[IV-44] Armor Joint Void	T										T				T	T					T						
47	Illustration-Metal Bar Chairs	T					T	T			T															T		
48	Illustration-Screed Mechine	T		T		T						T		T											T			
49	LL01R9301-Lita Pole Vibratn										T						T										T	
50	LL01R9401-Deck Striping										T	T			T		T										T	

Figure 5.1 - IN REACH “Classification” Database for the Subcategory of Bridge Deck

BRIDGE DECK CONFIGURATION DATABASE	
CODES	**SUBJECT HEADINGS**
A	Placement
B	Curing
C	Finishing
D	Surfaces
E	Equipment
F	Rebar
G	Formwork
H	Removal
I	Stay-in-place
J	Materials and Accessories
K	Concrete
L	Metal
M	Screeding
N	Grooving
O	Inspection
P	Special; Requirements
Q	General Requirements

Figure 5.2 - IN REACH "Configuration" Database for the Subcategory of Bridge Deck

on the right side of the table). These entries (R1 through R10) are matched to the ten source documents as reviewed in Chapter 4. The corresponding description for each these source entries is imbedded within IN REACH's program code as listed in Appendix M. Copies of all three "classification" tables and their corresponding "configuration" tables have been included in this dissertation as Appendix N.

With respect to the searching routines associated with these databases, the IN REACH prototype system made use of another add on package developed by Knowledge Garden Inc. called KPWin SQLKIT. As was presented in Chapter 3, IN REACH employs the standard SQL "SELECT" command for retrieval of network nodes matching user supplied criteria. Each data field in the classification table is marked as either true (T) are false (blank) thus linking each node to a set of distinct attributes. These attributes along with their corresponding node description (the second column from the left in Figure 5.1) make up the individual record. Details of how these queries or searches are preformed, from the perspective of the user, will be demonstrated latter in this chapter when a guided tour of the IN REACH system is presented.

5.3.4.3 Expert systems programming strategies

As was noted in Chapter 3, the integration of expert systems into the prototype system would be accomplished by utilizing a forward chaining inference strategy on a generic set of IF...THEN rules. Details of the actual system code can be found in Appendix M, documented as the "RELATED TOPICS SUBROUTINE." However, in general programming terms, the following steps occur upon activation by the user of the related topics search routine:

1) IN REACH identifies the particular node that the user is on when the related topics routine is activated.

2) The system locates this node in one of the three subcategory classification databases.

3) IN REACH counts the number of fields under the subject headings where a value of true (T) appears.

4) Chaining through a set of generic rules specific to the number of true occurrences, IN REACH returns an array of all other nodes in the network that qualify as related based on this rule set. The rules have been developed so as to give a higher priority to the nodes that reside within the same classification database as the one that contained that node from which the user initially activated the related topics search routine.

As was the case with the relational database management programming strategies, details of the performance of this routine, from the perspective of the user, will also be demonstrated latter in the next section of this chapter which will present an overall guided tour of the IN REACH prototype system.

5.4 A Guided Tour of the IN REACH Prototype System

5.4.1 Introduction

This guided tour of the IN REACH prototype system will begin at the beginning. Figure 5.3 illustrates the very first screen that the user encounters upon activating the IN REACH program. From this point, the user can either "CONTINUE," read an online "INTRODUCTION" of the system's features, or "EXIT" by clicking on the appropriate button. Assuming the user clicks on "CONTINUE," the next screen that will appear is depicted in Figure 5.4. From this screen the user can select one of the six "General

Figure 5.3 - IN REACH Welcome Screen

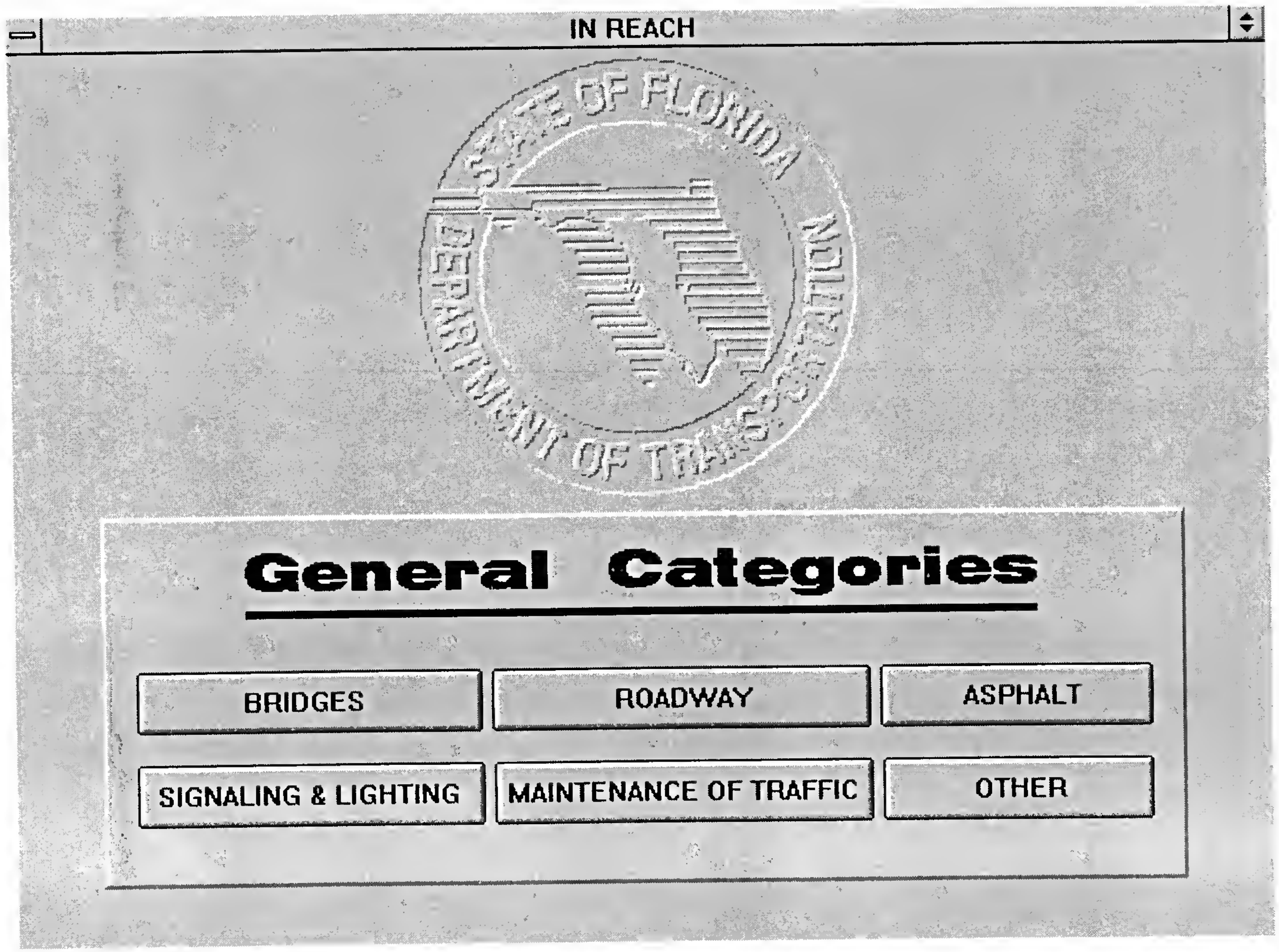


Figure 5.4 - IN REACH General Categories Screen

Categories" listed. As has been noted on numerous occasions however, if the user clicks on anything other than "BRIDGES," a message will pop up saying that the general category selected is not yet available under this version of IN REACH. Therefore, it will be assumed that the user chooses "BRIDGES," which will cause IN REACH to display Figure 5.5, which is the same image as displayed in Chapter 4 (Figure 4.25).

5.4.2 The IN REACH User Interface Layout and Basic Functions

5.4.2.1 The four viewing windows

Continuing as per Figure 5.5, the screen is divided up into four main windows. The largest window, in which the Skyway Bridge image along with some text presently is displayed, is the main viewing window wherein IN REACH displays the current hypertext node. This window has a vertical scroll bar for viewing nodes that require more than one screen of display area, as was the case with Figures 4.17a and 4.17b of Chapter 4. The smaller window at the top right corner of the overall display screen contains the listing of the "Navigational History." This window in essence keeps track of where the user has been, in this instance he or she has only been to one screen "BRIDGES." As is the case with all four of the windows, this window also has vertical scroll capabilities. The next smaller window, in the middle of the stack of three, is called the "Search By" window, and is activated when the user clicks on the "Search By" button contained in the button bar (located directly above the Skyway Bridge image). Details of this windows functions will be presented latter in this section. The fourth window is the "Related Topics" window, activated when the user selects the "Related Topics" searching routine, details of which will also be demonstrated later in this section.

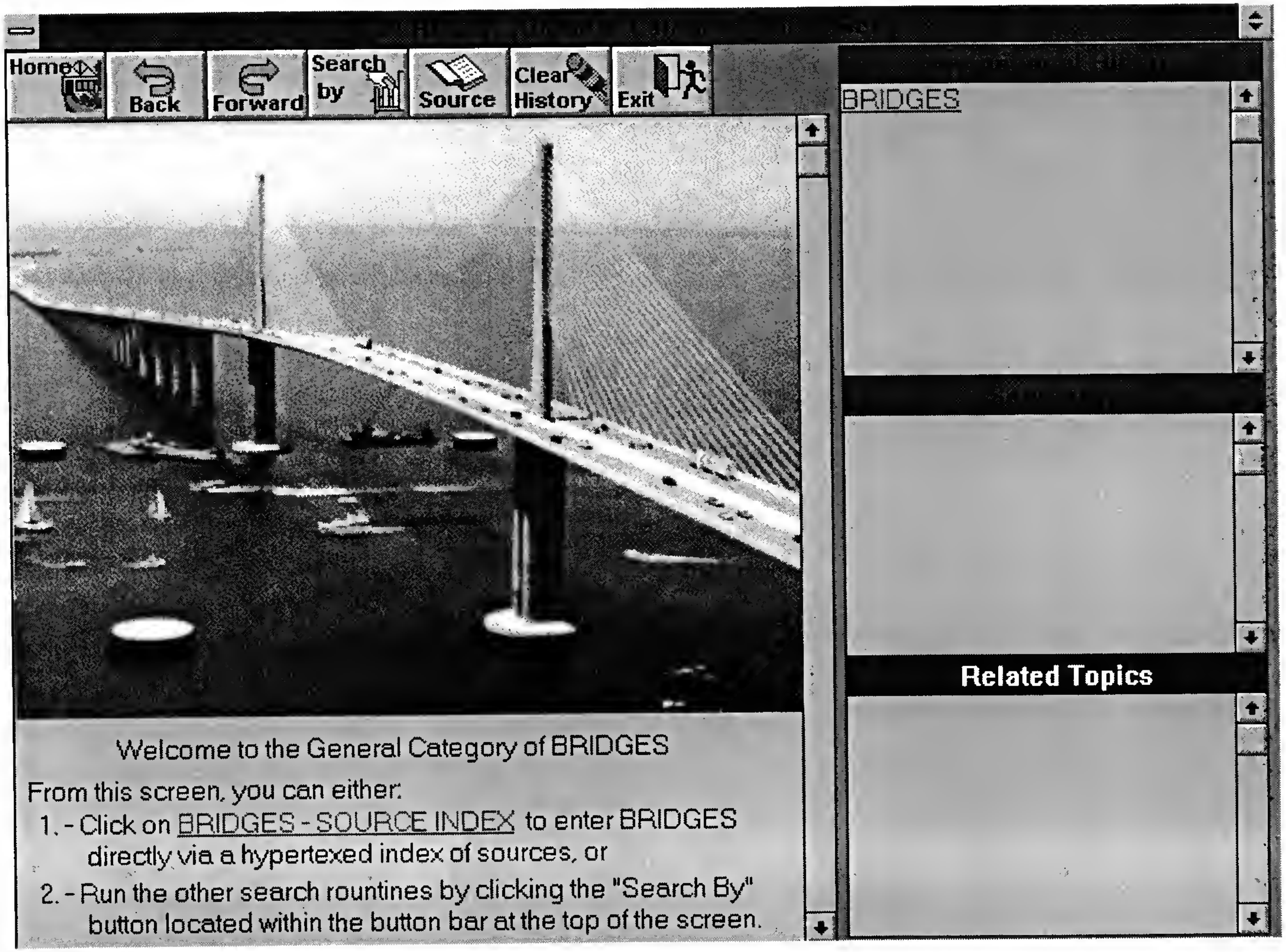


Figure 5.5 - IN REACH Home Screen for General Category of BRIDGES

5.4.2.2 A brief look at each of the seven buttons contained in the button bar

The button bar, located at the top of the main viewing window, contains seven buttons. A brief review of each is presented as follows working left to right across the button bar:

1) "Home"--This button takes the user back to the home (front) screen of whichever general category that user happens to be in. Figure 5.5 displays the home screen of the general category of "BRIDGES."

2) "Back"--This navigational feature takes the user back one screen to the previously occupied screen.

3) "Forward"--This button only works if the "Back" button has been used, and if so, it drives the user forward one screen from his or her present location along the same path traveled via use of the "Back" button.

4) "Search By"--Clicking on this button activates the "Search By" window as illustrated in the zoomed in image of Figure 5.6. The three basic search routines ("List of Topics," "Sub Categories," and "Related Topics") can be activated at this point. Again further discussion on these routines will be visited later in this section. IN REACH also provides a "Cancel" button in case the user wishes to cancel his or her initiation of the "Search By" routine.

5) "Source"--This button can be clicked on at any time to display a pop up window which informs the user from what source the current node was obtained. Figure 5.7 is an example of the user activating the "Source" button from the topic (node) whose file name is "A455-3.2.1 excavation," and document source is the FDOT Supplemental Specifications.

6) "Clear History"--This button allows the user to clear the "Navigational History" window at any time during use of the program. This same button changes to read "Clear Illust." when the user clicks on a graphical hot key (a string of text whose name begins with "Illustration-"). After viewing the graphical image, the user can click on this button to clear the illustration, and return to the topic screen from where the illustration was originally accessed.

7) "Exit"--this button will take the user completely out of IN REACH and returns him or her to the Windows Program Manager.

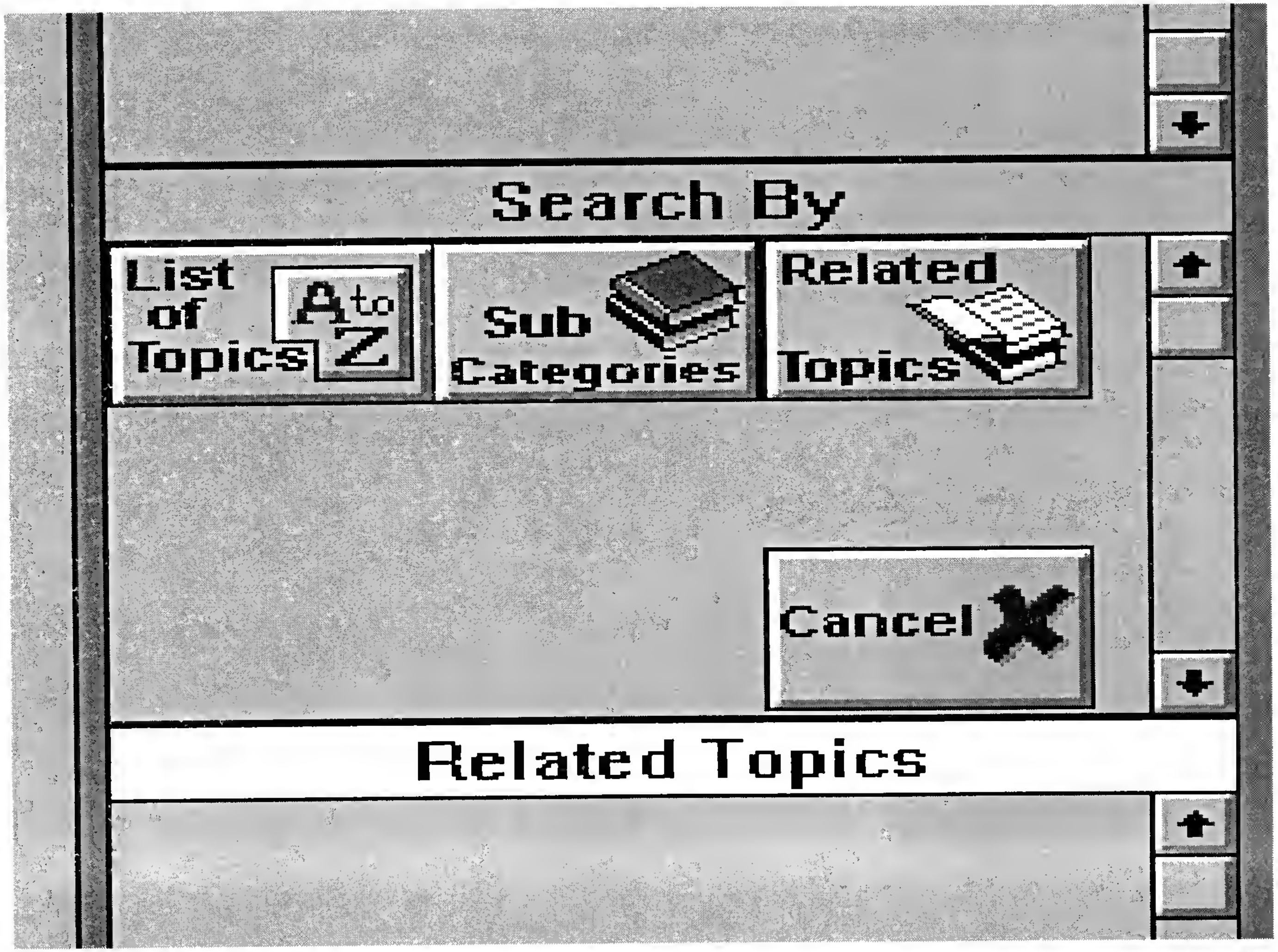


Figure 5.6 - IN REACH Zoomed In View of the Activated "Search By" Window

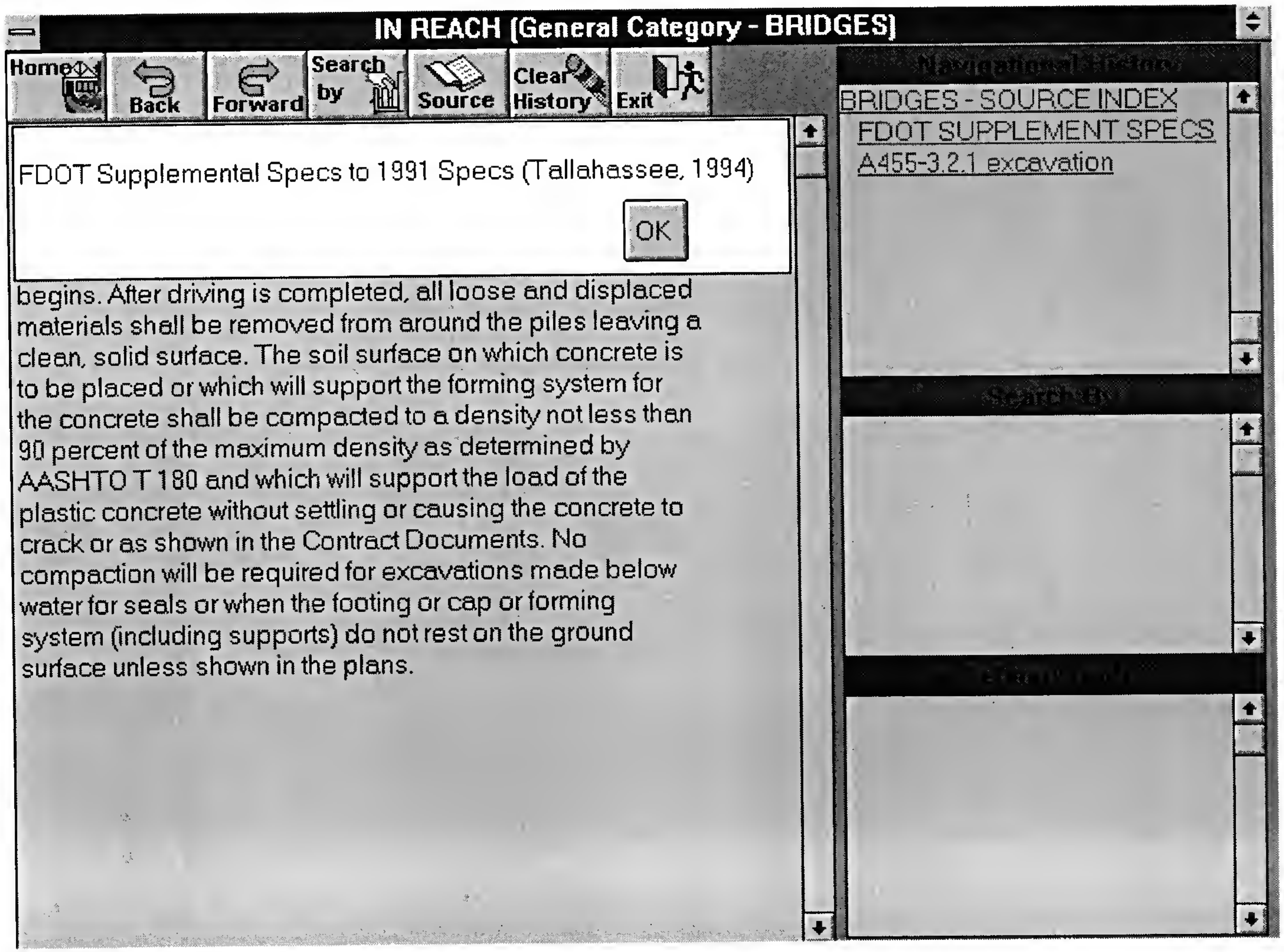


Figure 5.7 - IN REACH Example of Activation of the "Source" Pop Up Window

5.4.3 A Closer Look at the Three "Search By" Routines

5.4.3.1 General comments

As was previously noted, when the "Search By" button in the button bar is clicked on, the three search routines ("List of Topics," "Sub Categories," and "Related Topics") as illustrated in Figure 5.6 become available to the user. Presented next will be a closer look at each of these three options.

5.4.3.2 The "List of Topics" routine

This routine was developed as a method of assisting an experienced IN REACH user to quickly localize the topic (node) which he or she is looking for. The user simply clicks on the "List of Topics" button in the activated "Search By" window of Figure 5.6, and the screen as displayed by Figure 5.8 will automatically pop up in the main viewing area. From this routine, the user can begin typing a topic name in the entry box (the blank box at the top of the list). It should be noted that this list contains every topic currently in the system sorted in alphanumeric order. This list has been programed to be progressively character sensitive so that as the user types in characters, the list automatically scrolls to that particular location. In other words if the user typed in for example an "I," then the list would scroll down from its present position, as shown in Figure 5.8, to its new position as depicted by Figure 5.9. The user also has the option of manually manipulating the scroll bar until the desired topic is within the viewing area. Either way, once the user has found a particular topic, he or she only needs to highlight it so it appears in the entry box. At this point a simple click of the "GO TO" button will display this selected node in the main viewing area.

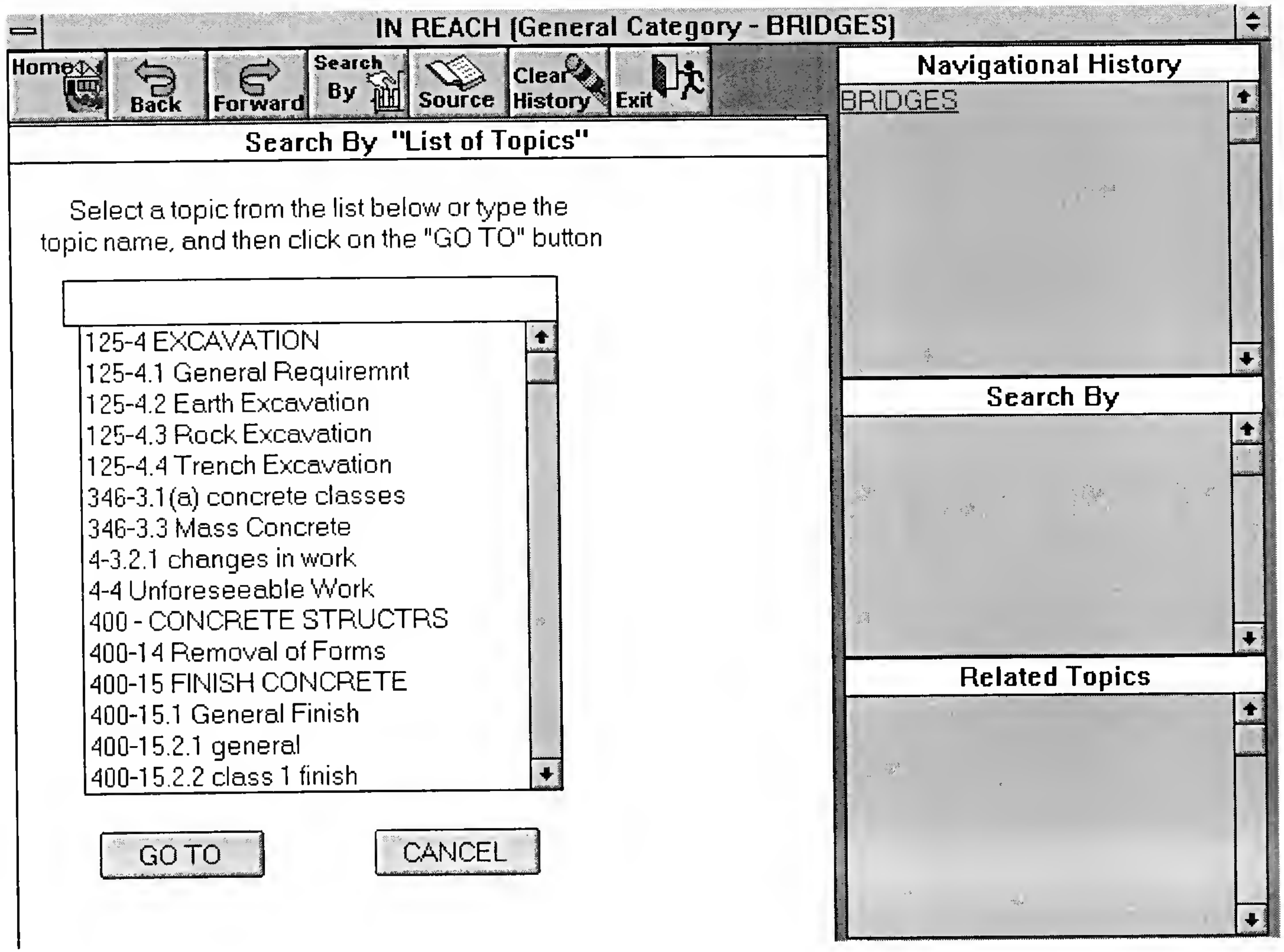


Figure 5.8 - IN REACH Example of "List of Topics" Serach By Routine

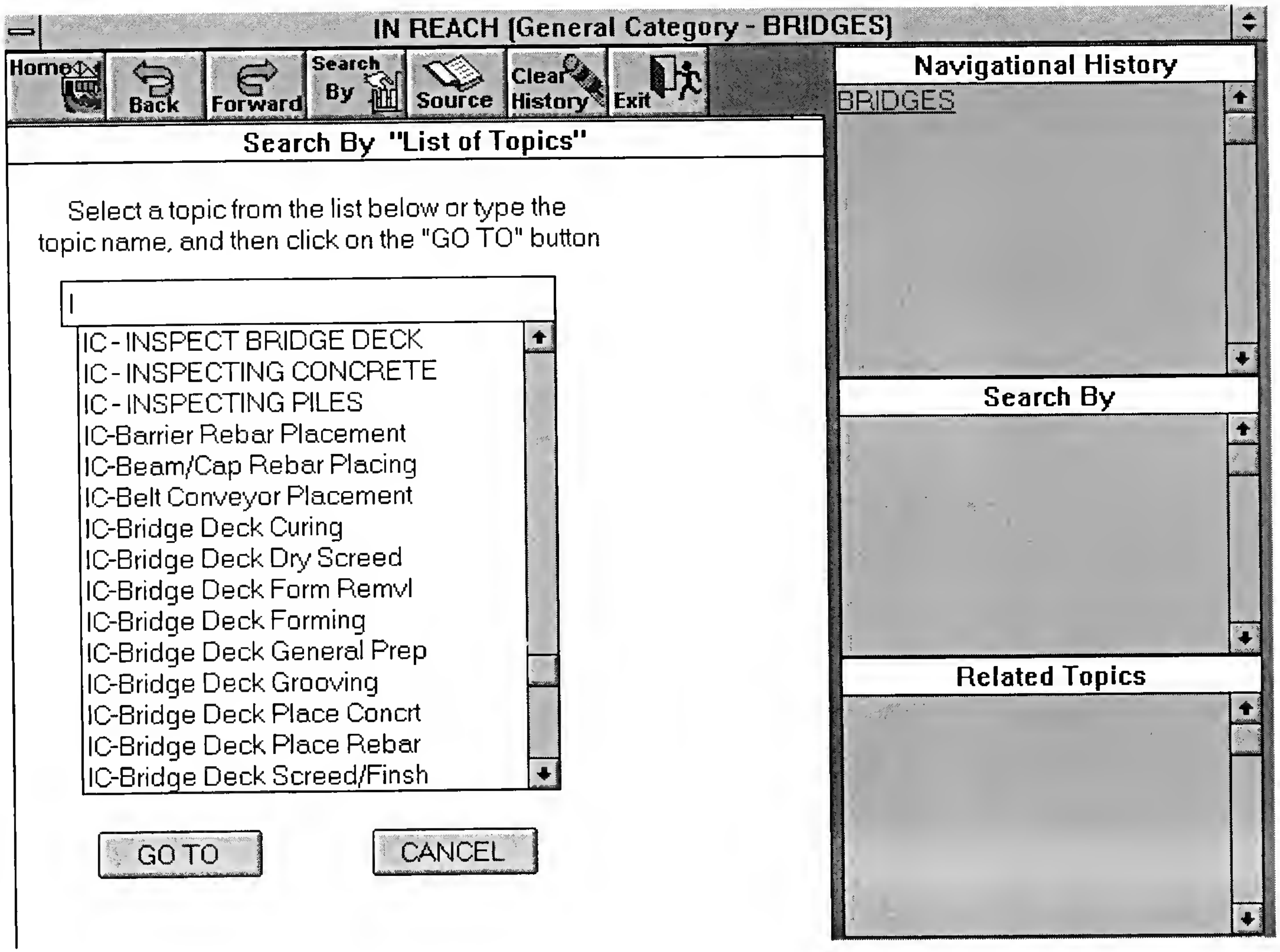


Figure 5.9 - IN REACH Example of “List of Topics” Scrolled Down to the Letter “I”

5.4.3.3 The "Sub Categories" routine

This routine directly accesses the three "classification" databases that were discussed earlier. Clicking on the "Sub Categories" button, as shown in Figure 5.6, causes the system to superimpose the three subcategory buttons of "Piles," "Bridge Decks," and "General Concrete," as illustrated by Figure 5.10. As an example of how this routine functions, assume the user selects the "Bridge Deck" subcategory button. Given that this is the case, the entire viewing screen will then be occupied by the "BRIDGE DECK" subcategory window as shown in Figure 5.11. The box on the left contains the predefined decoded list of subjects contained in the classification database, as per Figure 5.1. The box on the right contains the list of the ten document sources.

At this point in the routine, the user can define his or her query by simply highlighting those subjects of interest. The IN REACH search pattern is based on the Boolean "AND" querying strategy. In other words, if for example, the user wanted to select all records within the "Bridge Deck" subcategory that were linked to at least the subjects of "Placement" and "Rebar," he or she would highlight those two subjects, as illustrated in Figure 5.12. The user can then either filter the results of the search by selecting (highlighting) a particular source in the "Sources" box on the right, or allow IN REACH to apply the default setting, which searches through all source documents. Assume the user in this example choose the latter (all sources), he or she need only then to click on the "GO" button. This action will cause IN REACH to return the "Result(s) of Search" as a list of topics that match the user's query. Continuing with this example, Figure 5.13 illustrates the scenario just described. If these results are unacceptable, the user can rerun the search, which will return the system to the earlier viewed screen of Figure 5.11 by clicking the "TRY AGAIN" button. However, if the

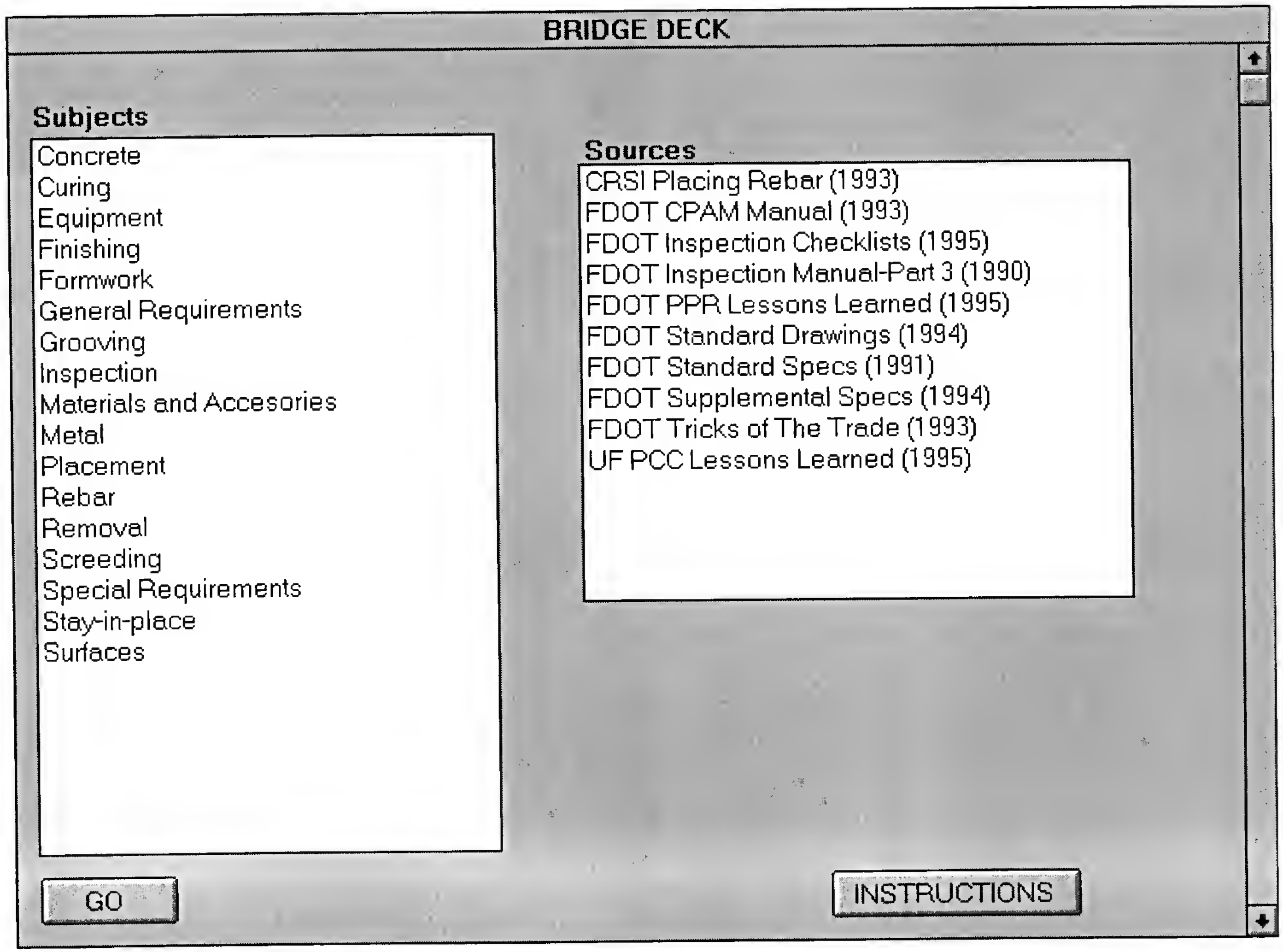


Figure 5.10 - IN REACH Example of Superimposed Subcategory “Search By” Options

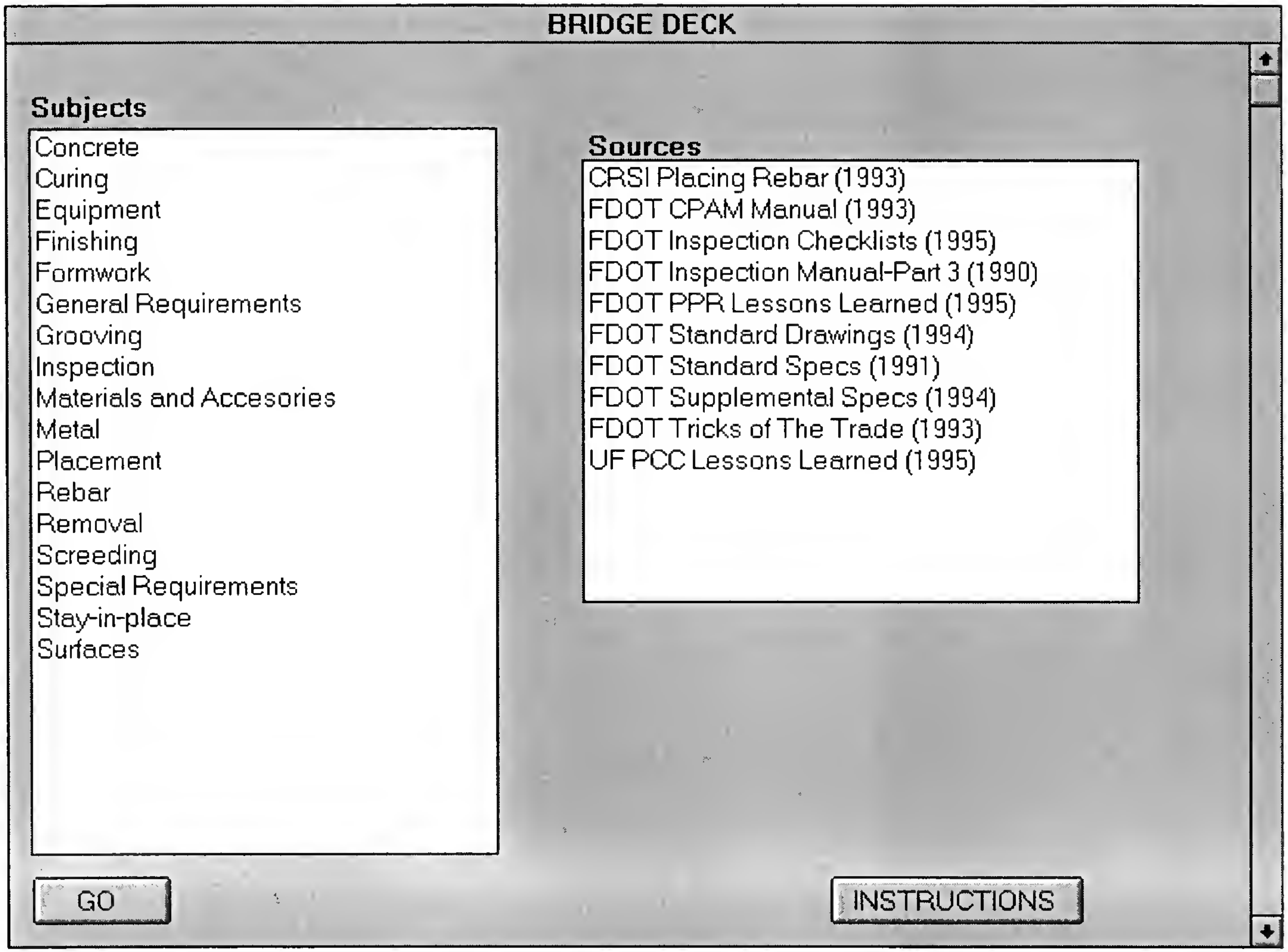


Figure 5.11 - IN REACH Example of the "BRIDGE DECK" Subcategory Window

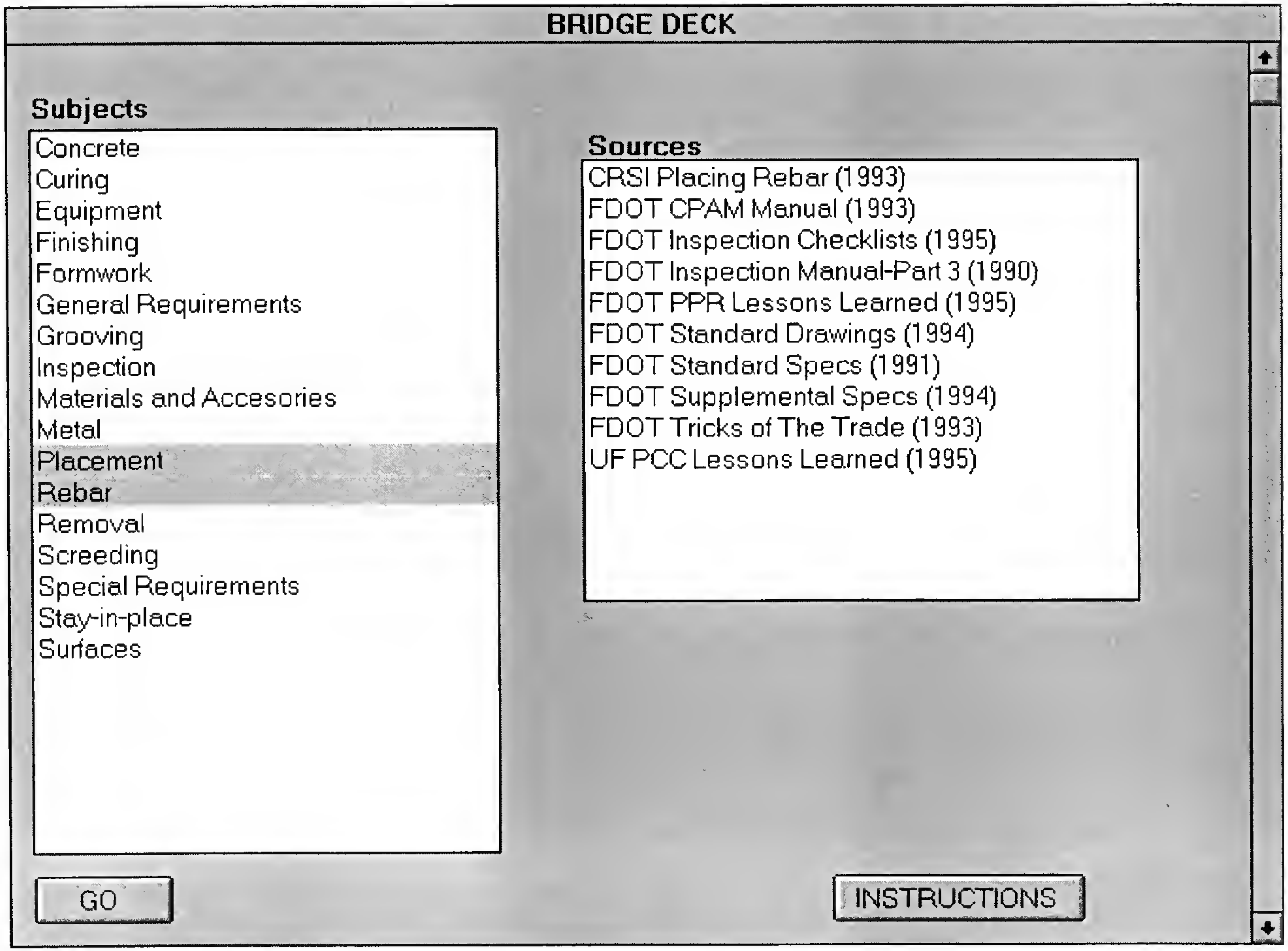


Figure 5.12 - IN REACH Selected Subjects for the “BRIDGE DECK” Example

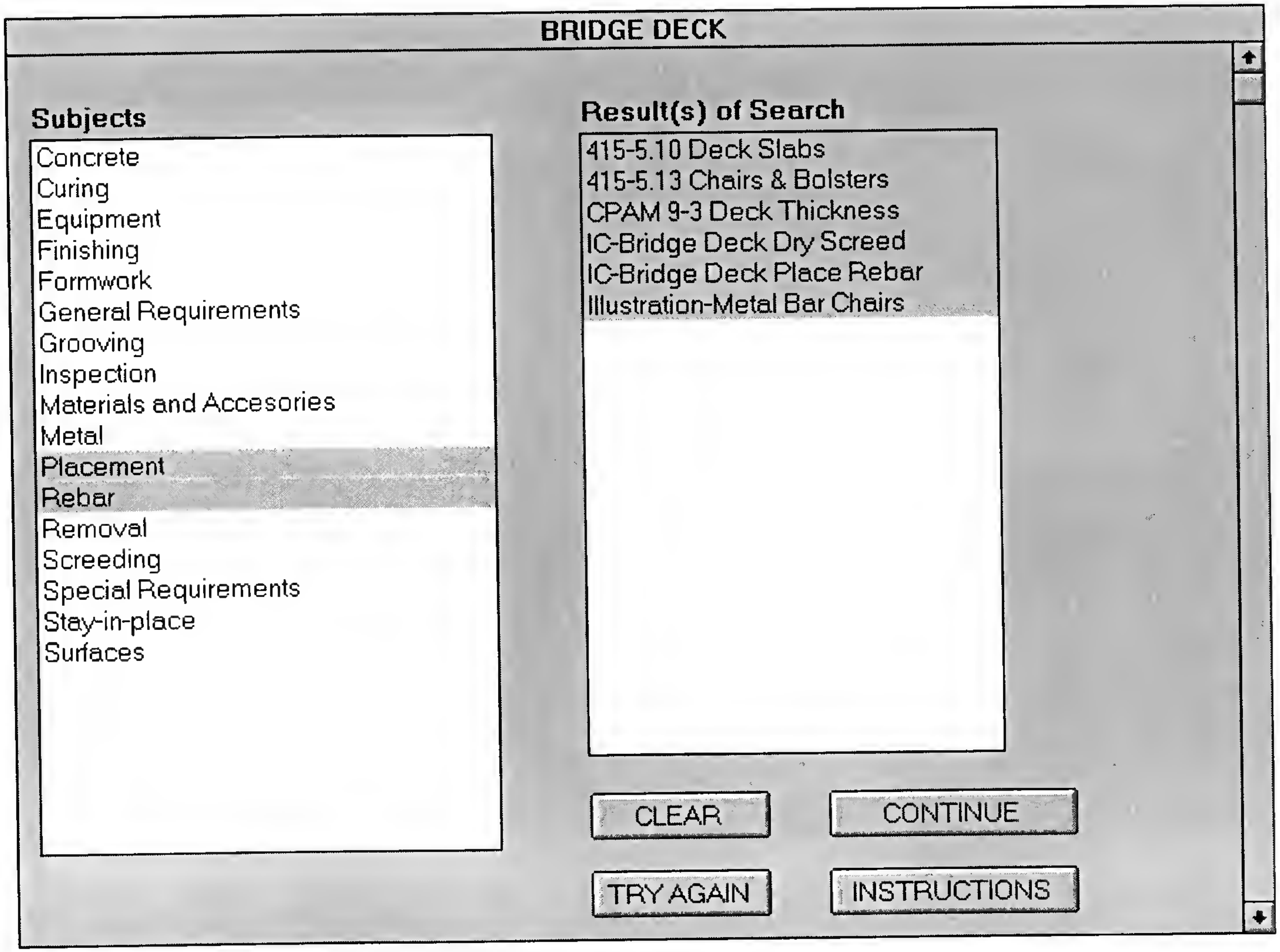


Figure 5.13 - IN REACH "Result(s) of Search" for the "BRIDGE DECK" Example

results are satisfactory, the user can either highlight certain topics, are highlight them all by clicking the "ALL" button, which is the case in this example as shown in Figure 5.13. Finally, by clicking on the "CONTINUE" button, these results are returned back to the standard IN REACH user interface for continued hypertexted browsing as illustrated by Figure 5.14. One other note to this example, is that the user can click on the "INSTRUCTIONS" button at any time from the subcategory search screen (Figure 5.11 through Figure 5.13) to receive online instructions with respect to how this routine operates.

5.4.3.4 The "Related Topics" routine

This is the third and most ambitious of the advanced searching routines available from the "Search By" window, as per Figure 5.6. As was previously explained, the concept of this routine is to identify the current node, and return to the user all other nodes within the IN REACH system that are determined to be related. To demonstrate how this routine works, the "BRIDGE DECK" example represented in Figure 5.10 through Figure 5.14 will be continued. Assume that upon return of the "Result(s) of Search" to the standard IN REACH interface (Figure 5.14), the user decides to look at the topic called "415-5.13 Chairs & Bolsters" by clicking on the hot key as it appears in the "Result(s) of Search" window (Figure 5.14). This action will cause IN REACH to display this topic in the main viewing window as shown in Figure 5.15. This figure also incorporates the additional "Related Topics" search that was performed, whose results now appear in the "Related Topics" window. Figure 5.15 now contains the results of the subject search in the subcategory of "BRIDGE DECKS," as well as the related topics search, which encompasses the whole system. Notice how the "Related Topics" list differs from the "Result(s) of Search list, focusing more directly on bar

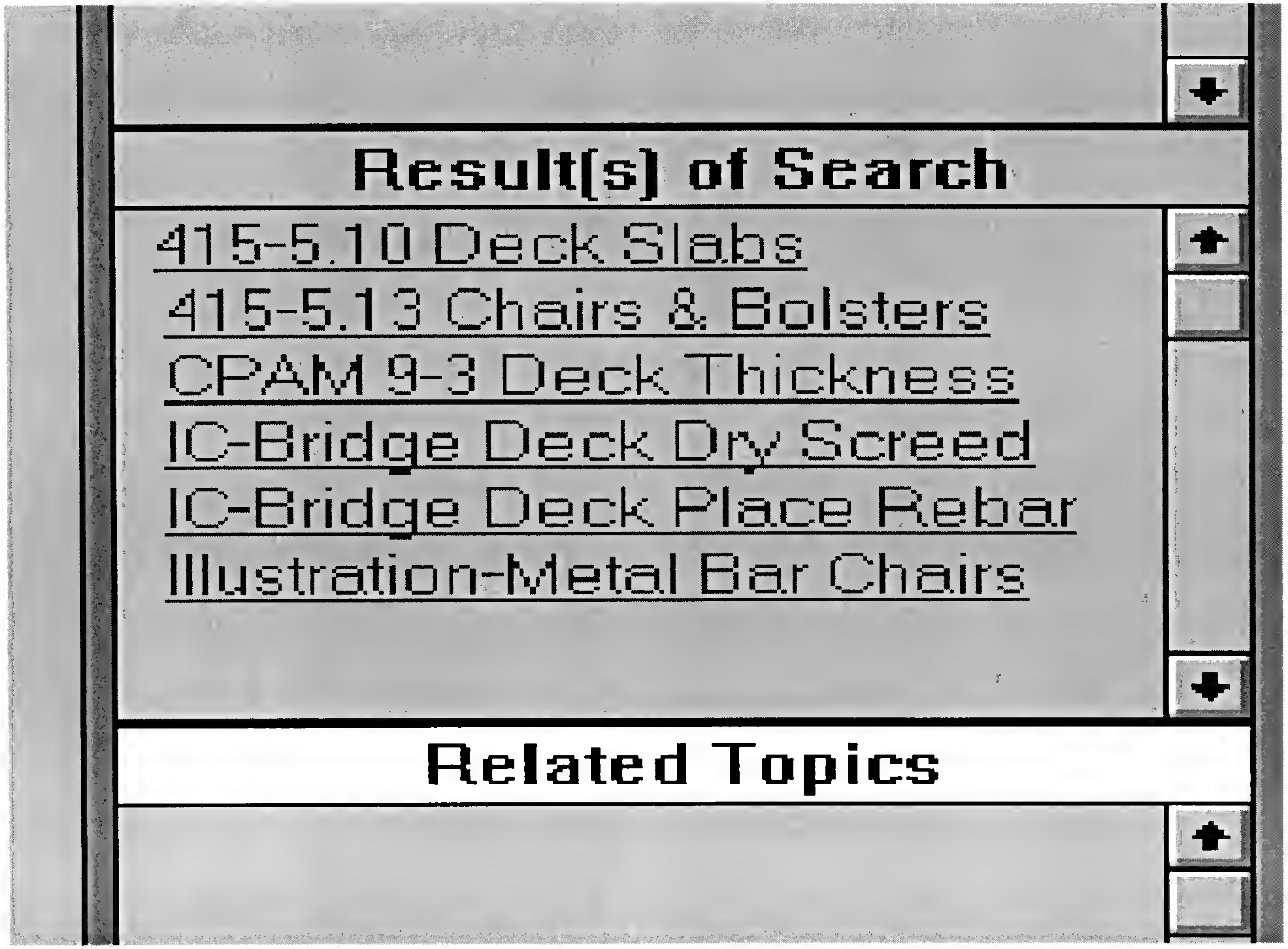


Figure 5.14 - IN REACH Return of the “Result(s) of Search” to the Standard Interface

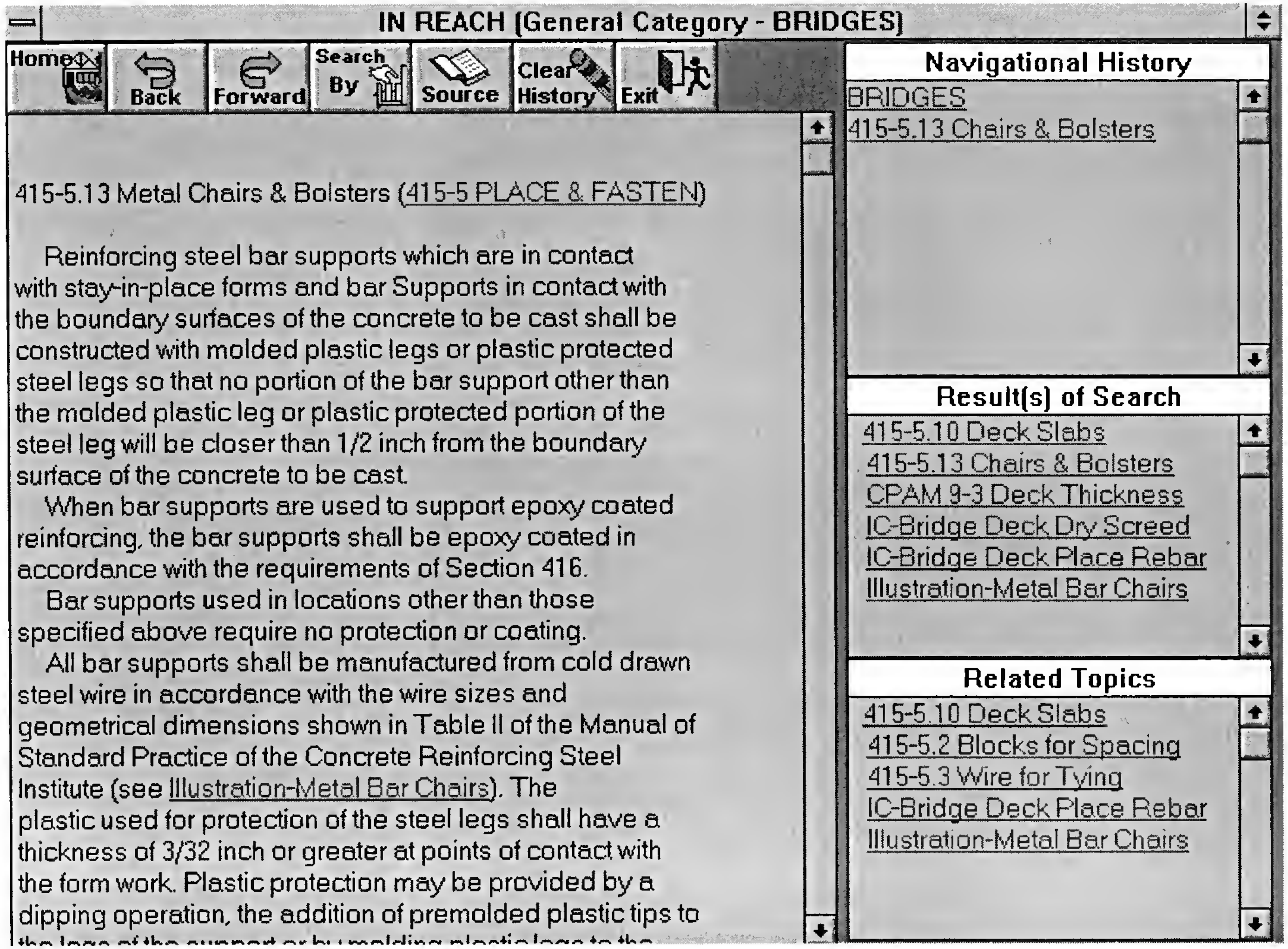


Figure 5.15 - IN REACH “Related Topics” Example for “415-5.13 Chairs & Bolsters”

chairs, as well as actually accessing two new related topics ("415-5.2 Blocks for Spacing" and "415-5.3 Wire for Tying") from the subcategory of "General Concrete."

5.5 Testing of the Prototype System

5.5.1 General Comments

The IN REACH prototype system is exactly as its name implies, a "prototype system." What this suggests is that the current version of IN REACH is relatively limited and experimental, developed as an illustrative tool for displaying this dissertation's proposed approach. As such, a full-blown testing strategy would not necessarily be the most prudent path to follow. However, it was felt that it would be worthwhile to conduct a variety of structured demonstration sessions, as well as distribute prototype copies of IN REACH to selected FDOT personnel for their unsupervised use. Both of these strategies were effected, details of which will be presented next.

5.5.2 Structured Demonstrations of Preliminary Versions

Preliminary versions of the IN REACH prototype system were demonstrated to a number of FDOT personnel in an effort to solicit their suggestions for possible enhancements to the final prototype version. Albeit the system is geared towards novice practitioners, it was felt that developmental demonstration sessions, for the purposes of system improvements, would be more effective when conducted among veteran practitioners, namely because they are more familiar with the requirements of the Department and its workforce. Although at the time of these structured demonstrations, the preliminary versions of IN REACH were still experiencing minor operational difficulties, or more commonly known as bugs, these sessions proved to be very useful.

Of all the comments gleaned from the demonstration sessions, the most common suggestions were centered around the provision of more information with respect to the sources of the various hypertext topics (nodes). Early versions of IN REACH did not furnish this type of information to the user. These comments directly led to the development of two of the now established features of the current IN REACH prototype system. One result of these demonstration meetings was the creation of the "Source" button, which was detailed in earlier commentaries and illustrated in Figure 5.7. The other source related feature that evolved from preliminary FDOT comments was the concept of allowing the user to filter the "Sub Category" "Search By" routine by specifying desired document requirements. This idea has also already been presented with respect to the discussions associated with Figure 5.11 through Figure 5.13. Whereas the value of the structured demonstration sessions certainly was realized, the true measure of the system's success would come from distribution of the IN REACH program for unsupervised testing by those personnel who would ultimately be using the system.

5.5.3 Distribution of Prototype System for Unsupervised Testing

This phase of the testing process would more clearly indicate the relative success or failure of the developmental system. The thought was to distribute to the target audience, a self-contained minimal diskette package, along with a set of limited instructions, and then ask them to install the program and run it at their convenience. Upon completion of their trial use of IN REACH, it was requested that they answer a couple of short questions regarding their impressions of the prototype system. The makeup of the selected distribution list was as follows:

One FDOT Professional Engineer Trainee

One FDOT Assistant Resident Engineer

One FDOT Construction Quality Engineer

One FDOT Resident Engineer

One CEI Office Engineer

One CEI Project Engineer

For distribution purposes, the IN REACH KPWin programming code, as per Appendix M, was complied using KPWin ++ in conjunction with Microsoft Visual C++ version 1.52. In addition to this generated executable (.EXE) file, all other required external files and libraries were copied onto a set of four 3-1/2 inch, high density diskettes. In order to be able to load these diskettes, the potential user's computer needed to have at least five megabytes of free space on the hard drive. Additionally, as has been noted, the Windows operating system was also a requirement. Along with the diskettes, a two page cover letter explaining how to install and run IN REACH, as well as a Reviewer's Comment Sheet, both of which are contained in Appendix O of this dissertation, were included in the overall distribution package. Of the six packets that were mailed out, four completed comment sheets were received. The results from the respondents to the four basic Comment Sheet questions were as follows:

1) *Question A*--This first question measured the reviewer's opinion on the "user- friendliness" of IN REACH. All four reviewers answered that this category rated as Above Average.

2) *Question B*--This question wanted to determine the reviewers opinion on the effectiveness of the strategies employed by IN REACH regarding organizing and accessing highway construction information. Two of the reviewers rated IN REACH as Superior in this regard, while two rated the program as Above Average.

3) *Question C 1*--Here the question requested a rating on the potential effectiveness of an IN REACH type system with respect to assisting the reviewer in accomplishing his or her typical job description duties. The results of this question were that one reviewer rated the system as superior and three said it was Above Average.

4) *Question C 2*--This question was only meant for veteran practitioners, and it asked them their opinion regarding IN REACH's potential for assisting novice personnel. On this particular point, all three veteran reviewers agreed that IN REACH represented a Superior approach for assisting novice practitioners.

As for the individual, unprompted comments, there appeared a consensus among three of the four reviewers with respect to graphical images. In essence, the reviewers felt that the system would be greatly enhanced by the use of more illustrative information. In fact one reviewer suggested fully incorporating other multimedia features such as sound and video. Unfortunately, at this point, development of the first IN REACH prototype system has been completed, and these requests for more multimedia capabilities will have to be addressed in future versions of IN REACH, if so sponsored.

5.6 Final Comments

Results of the testing and demonstration procedures associated with the IN REACH prototype system basically confirm that on a common level, the targeted end user, FDOT construction personnel, generally appreciated the research effort and recognized the future potential for intelligent information management systems. This dissertation's originally stated objective of integrating the three distinct computer technologies of expert systems, hypertext, and database management systems, into one user-friendly, intuitive programming environment, seems to have been realized.

Although by no means conclusive, all indications from preliminary interactions with FDOT construction personnel have demonstrated that there may be a place in the Department for an IN REACH type of system which could assist veteran and novice practitioners alike. This is not to say that there is no room for improvement of the IN REACH prototype system. On the contrary, this research endeavor essentially solved as many problems as it uncovered. Chapter 6, along with a overview of the entire project, will present several recommendations for proposed enhancements to the basic IN REACH prototype system.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 General Comments

This research endeavor represented a comprehensive study of the problems associated with the development of a systematic approach for capturing the knowledge and experience of a large organization, and establishing a computer delivery system for dissemination of this encoded information. Fundamental to this delivery system was the creation of a user-friendly computing environment that would provide an intuitive tool capable of assisting both veteran and novice practitioners in fashioning more informed decisions concerning problems that may arise during normal and abnormal highway construction operations. Presented next will be a final overview of this dissertation's effort, incorporating a look back at the original research objectives, coupled with a comparative discussion of whether or not these stated objectives were actually accomplished. Additionally, this chapter will include a section on recommendations for future enhancements to the current version of the IN REACH prototype system.

6.2 A Summary of the Originally Stated Research Objectives

6.2.1 General Comment

The originally stated overall goal of this research project was to develop a systematic approach for gathering highway construction knowledge and experience, organizing this information, storing it, and presenting it in such a fashion as to be readily accessible and useful to anyone wishing to benefit from this captured base of knowledge and expertise. This broad effort will now be summarized in terms of three basic objectives for further review.

6.2.2 Summarized Objective Number One

The first basic stated objective can be summarized as the requirement for the identification of the specific area of highway construction operations wherein there was industry consensus that the particular domain identified represented acute dependence on veteran knowledge and experience for successful job performance.

6.2.3 Summarized Objective Number Two

Once the specific domain was established, the second basic research objective was the development of the focused knowledge base, with emphasis on a systematic effort that would enable ease of future expansions.

6.2.4 Summarized Objective Number Three

With the knowledge base in place, the third objective was to research and develop an information management system that would operate under a user-friendly environment wherein novice and expert personnel alike, would be able to effectively utilize the system.

6.3 A Review of Whether or Not the Objectives were Accomplished

6.3.1 General Comment

Although this research encompassed more than just simply addressing the stated objectives, a review of the efforts required to accomplish these objectives will allow for discussion of most of the major topics covered in this dissertation.

6.3.2 Reviewed Accomplishments as per Objective Number One

From the results of the KA & EC questionnaire, a consensus, both nationally and within the FDOT, was realized. The identification of new bridge construction with an emphasis on inspection operations was a clear choice for the focused domain. Additionally, by means of a survey of current practices, utilizing both the KA & EC questionnaire results, as well as a variety of other resources, this dissertation was able to ascertain what programs existed and were being implemented within the industry for the acquisition and capture of highway construction knowledge and experience.

6.3.3 Reviewed Accomplishments as per Objective Number Two

As has been noted, originally, research efforts were concentrated on the expert systems approach. However, soon into the project, it was determined that this strategy

would not effectively accomplish the stated objective. With this in mind, the direction of the research was reevaluated and it was decided that the applied approach of developing a specialized preliminary knowledge base of documented information, supplemented by PCC lessons learned comments would be pursued. Chapter 4 of this dissertation does a very thorough job of covering this particular topic, and as such there is no need to discuss this approach in detail again. However, it should be emphasized that the knowledge base structure was developed with a modular design in mind so as to facilitate ease of future expansion to the system. Another point to be made, is that both the documented knowledge base developmental strategy, and the proposed implementation of a state wide PCC program, addressed the stated objective with respect to a systematic approach.

6.3.4 Reviewed Accomplishments as per Objective Number Three

Probably the most ambitious of the three stated objectives, was this dissertation's decision to attempt a computerized integration of the distinct software technologies of expert systems, hypertext and database management systems. Given that a fundamental understanding of these systems did not exist at the start of this research effort, the literature review, as detailed in Chapter 3, was focused heavily on developing a underlay comprehension of each of these information management techniques, in order that an informed determination could be made on which aspects of which technologies should be utilized. Although not to belabor the point, it will be reiterated herein that the basic decision was to develop an underlying hypertext system augmented by the database modeling concepts of both the hierarchal and relational models, with the relational tables enabling the user to directly query the hypertext network. Additionally, as has been noted, the expert

systems approach was incorporated as a method of developing the "Related Topics" routine utilizing an imbedded forward chaining inference strategy.

Again the idea of a modular design should be emphasized with respect to the relational "classification" databases. From reading this dissertation, it should be apparent that the limited base of the IN REACH prototype system only contained the three subcategory databases of "Bridge Deck," "Piles," and "General Concrete," within the single general category of "BRIDGES." However the modular nature of relational tables makes expansion of the system's database functions a relatively painless experience.

6.3.5 Final Comments

The discussion of whether or not the originally stated research objectives were accomplished, seems to suggest that in general terms they were. However, as noted earlier, accomplishment of the research objectives does not necessarily indicate that there is not room for improvement. This being the case, the next section will examine a few of the recommendations for future enhancements to the current IN REACH prototype system.

6.4 Recommendations for Future Enhancements to the Prototype System

6.4.1 Software Enhancements

Although selection of KPWin as this dissertation's developmental environment was well researched, it is next to impossible to fully appreciate all aspects of a particular software package until work is actually done on the system. Originally, the SQLKIT was utilized for database querying. In retrospect, albeit that this add on package accomplished the task at hand, it probably would have been more effective to develop the relational query aspects of

the IN REACH prototype system with an alternate KPWin add on package which they call KPWin DBASE Kit.

6.4.2 Development of a More Sophisticated Rule Set

Use of the expert systems capabilities for the IN REACH prototype system were relatively elementary due to the fact that the knowledge base, with respect to the number of hypertext nodes (approximately 300), was rather limited. In other words, due to the fact that there were only 300 or so nodes to manipulate, the rule set with respect to the "Related Topics" routine had to remain somewhat unsophisticated so as to allow for topic matches. This unfortunately created the undesirable occurrence from time to time of returned related topics that were not that closely related. However, given that the research was conceptual, the idea of dynamic linking via the "Related Topics" routine is still valid.

6.4.3 Incorporation of More Multimedia Features

As was noted in the comments received during the testing of the IN REACH prototype system, there certainly is an industry demand for more multimedia type features, such as more graphics, as well as the inclusion of audio and video. Under the current Windows operating system, IN REACH probably could not handle much more graphical capabilities, as the system already was pushing against the conventional memory ceiling of 640K. However with the impending release of Windows 95, this inherent limitation probably would be resolved.

6.5 Final Comments on the Overall Research Effort

Today we find ourselves in the midst of the "Age of Information," poised to begin our travels along the information highway. For the highway construction industry, as well as society in general, the present scope of the electronic availability of information is staggering, and this is not even considering future projections. One might think that universal access to unlimited technical information would answer all the questions of how to acquire, store, transfer and exchange highway construction knowledge. But unfortunately, the answer is not so simple. This explosion of data has actually created an informational glut , and new technologies are developing in response to this deluge. The challenge has become how to organize and index all of this information in order to more intelligently access and utilize this enormous base of knowledge. IN REACH, although only a prototype system, may hold some of the answers to future strategies for intelligently managing information and knowledge.

APPENDIX A
KA & EC QUESTIONNAIRE

COLLEGE
OF
ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA 32611
DEPARTMENT CHAIRMAN
AREA CODE 904 PHONE 392-8537
STUDENT RECORDS
AREA CODE 904 PHONE 392-0933

Date:

Respondent's Name
Respondent's Title
Respondent's Organization
Address of Organization

RE: Knowledge Acquisition and Experience Capture Questionnaire

Dear Respondent's Name:

The Florida Department of Transportation, like many other state highway agencies, is facing a major problem of losing the acquired knowledge of veteran employees who leave the department through retirement, change of jobs, or for a variety of other reasons. These employees possess the equivalent of hundreds of years of accumulated experience, and if their expertise is not somehow collected and transferred, this valuable source of information will be lost forever. This predicament is especially acute in the realm of construction operations, where frequently the experience is not documented in any written form and usually kept only as personal knowledge.

The University of Florida is conducting research with the goal of developing a systematic procedure for gathering personal knowledge and experience, organizing this data, and storing it for future use. The attached questionnaire has been sent to you in an effort to ascertain how your organization addresses this problem of capturing the experience of veteran employees. At your discretion, please feel free to forward a copy of this survey to any departmental personnel, as well as anyone else, who you feel may be able to contribute additional information and insight with respect to this survey in particular, and the topic of knowledge acquisition and experience capture in general.

We realize that response to our survey will require the time and effort of some of the key personnel in your agency, and we fully understand the demands already placed upon your department. However, we feel that your participation is vital, and our study would be significantly deficient without your input. Upon completion of our research and publication of our findings, we will gladly forward you a copy of our report for your use.

Thank you in advance for all your cooperation, it will be greatly appreciated. We look forward to receipt of your questionnaire and encourage you to contact us directly to discuss any other ideas you may have regarding this study.

Please send any other pertinent information along with your completed questionnaire to:

Dr. Zohar Herbsman
University of Florida
Department of Civil Engineering
345 Weil Hall
Gainesville, FL 32611-2083
Telephone: (904) 392-0935
FAX: (904) 392-3394
E Mail: ZOHAR@CE.UFL.EDU

Sincerely,

Dr. Zohar Herbsman

FLORIDA'S CENTER FOR ENGINEERING EDUCATION AND RESEARCH

EQUAL EMPLOYMENT OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

KNOWLEDGE ACQUISITION AND EXPERIENCE CAPTURE

Respondent Information:

Date: ______________

Name: ______________________________

Title: ______________________________

Division/Unit: ______________________________

____

Agency: ______________________________

Address: ______________________________

____

Telephone: ______________________________

I. Loss of Veteran Employees

A. On a scale of 1 (lowest level of importance) to 5 (highest level of importance), what level of importance does your organization place on the loss of the acquired knowledge of veteran employees who leave your department through retirement, change of jobs or any other reason?

_____ 1. Lowest Level of Importance

_____ 2.

_____ 3.

_____ 4.

_____ 5. Highest Level of Importance

B. On average, how many veteran employees would you estimate that your agency looses per year?

____

C. What would be your best estimate of the gross number of years of experience lost due to this yearly departure of veteran employees?

____

Part I. Comments: (please use an additional sheet, if necessary)

____

____

____

____

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____

____

Please send any additional written or statistical data that your agency may have in regards to loss of experience due to the departure of veteran employees.

II. General Categories of Construction Work

A. Please rate on a scale of 1 (lowest significance) to 10 (highest significance) the effect to your agency that the loss of experience due to the departure of veteran employees has on the following general categories of construction work.

1. Bridge repairs & maintenance: Rating ______
2. New bridge construction: Rating ______
3. Roadway repairs & maintenance (other than asphalt): Rating ______
4. New roadway construction (other than asphalt): Rating ______
5. Asphalt repairs & maintenance: Rating ______
6. New asphalt construction: Rating ______
7. Signaling & lighting: Rating ______
8. Maintenance of traffic: Rating ______

B. Please list and rate any other general categories of construction work not specified above that may apply to your agency.

1. ______________________: Rating ______
2. ______________________: Rating ______
3. ______________________: Rating ______
4. ______________________: Rating ______

Part II. Comments: (please use an additional sheet, if necessary)

____

____

____

____

____

____

____

____

Person Completing Part II. (if different from Part I.)

Name: ______________________

Telephone: ______________________

III. General Areas of Construction Operations & Administration

A. Please rate on a scale of 1 (lowest significance) to 10 (highest significance) the effect to your agency that the loss of experience due to the departure of veteran employees has on the following general areas of construction operations and administration.

1. Constructability analysis: Rating ______
2. Inspection: Rating ______
3. Quality Control: Rating ______
4. Construction Documentation: Rating ______
5. Departmental Documentation: Rating ______

B. Please list and rate any other general areas of construction operations and administration not specified above that may apply to your agency.

1. ______________________________: Rating ______
2. ______________________________: Rating ______
3. ______________________________: Rating ______
4. ______________________________: Rating ______

Part III. Comments: (please use an additional sheet, if necessary)

____
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____
____
____
____
____
____

Person Completing Part III. (if different from Part I.)

Name: ______________________________

Telephone: ______________________________

IV. Knowledge Acquisition and Experience Capture

A. Has your agency ever developed in the past, is currently developing, or intends to develop in the future any written documentation or systematic procedure attempting to acquire and capture the experience and personal knowledge possessed by your veteran employees? If yes, please describe the program and indicate whether it was past, present or future.

If your answer to this question is NO, please feel free to continue with the questionnaire commenting on any of the remaining questions as you deem appropriate.

____

____

____

____

(please use an additional sheet, if necessary)

B. What methods did (or will) your agency utilize in its attempt to collect and capture for future use, the personal knowledge and experience of your veteran employees prior to their departure?

- ☐ One on one interviews with departing veteran employees
- ☐ Group roundtable discussions with departing veteran employees
- ☐ Requirement for all departing veteran employees to generate some sort of written operational / construction / inspection manual based on personal experiences
- ☐ Mentor / Apprentice (veteran employee / inexperienced employee) training system
- ☐ Requirement for all key personnel directly involved in a project to participate in post construction conferences and generate written reports based on these meetings
- ☐ Encouragement for all departing veteran employees to remain with the agency in some sort of part-time consultant capacity available as required by the agency
- ☐ Other: ______________________________
- ☐ Other: ______________________________

Please use the space below to briefly comment upon how the selected method(s) above were (or will be) specifically established and administered by your agency.

____

____

____

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____

____

____

____

(please use an additional sheet, if necessary)

IV. Knowledge Acquisition and Experience Capture (cont.)

C. After completion of the collection and capture phase of the knowledge acquisition effort, how did (or will) your agency store and distribute this information to the appropriate personnel?

____

____

____

____

____

____

(please use an additional sheet, if necessary)

Part IV. Comments: (please use an additional sheet, if necessary)

____

____

____

____

____

____

Person Completing Part IV. (if different from Part I.)

Name: ______________________________

Telephone: ___________________________

Final Comments: (please use an additional sheet, if necessary)

____

____

____

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____

____

____

If your agency has any written material concerning knowledge acquisition and transfer, such as inspection manuals, experience manuals, construction check lists, or any other documentation, reports or papers addressing this subject matter, the University of Florida and the Florida Department of Transportation would greatly appreciate you sending us a copy of any pertinent information along with your completed survey. Thank you again for all of your time and effort!!

APPENDIX B
DISTRIBUTION LISTS FOR THE KA & EC QUESTIONNAIRE

United States Distribution List for the North American Survey

1. State of Alabama Highway Department
   State Construction Engineer
   1409 Coliseum Boulevard
   Montgomery, AL 36130

2. Alaska Department of Transportation
   Chief Engineer
   3132 Channel Drive
   Juneau, AK 99801-7898

3. Arizona Department of Transportation
   Transportation Engineer Supervisor
   7755 S. Research Park Dr. - Suite # 106
   Tempe, AZ 85284

4. Arkansas State Highway and Transportation Department
   Training Engineer (Construction Division)
   PO Box 2261
   Little Rock, AR 72203

5. California Department of Transportation
   Chief - Division of Construction
   1120 N Street - Room # 3440
   Sacramento, CA 95814

6. Colorado Department of Highways
   Chief Engineer
   4201 East Arkansas Avenue
   Denver, CO 80222

7. State of Connecticut Department of Transportation
   Construction Administrator
   2800 Berlin Turnpike
   PO Box 317546-SE4
   Newington, CT 06131-7546

8. Deleware Department of Transportation
   North District Engineer
   250 Bear / Christiana Road
   Christiana, DE 19701

9. District of Columbia Department of Public Works
   Chief - Bureau of Transportation Construction Services
   2000 NW 14th Street - 5th Floor
   Washington, D.C. 20009

10. Georgia Department of Transportation
    Division Director - Construction
    2 Capitol Square, S.W.
    Atlanta, GA 30334

United States Distribution List for the North American Survey (continued)

11. Hawaii Department of Transportation
    Chief - Highway Division
    869 Punchbowl Street
    Honolulu, HI 96813

12. Idaho Department of Transportation
    Chief of Highway Operations
    311 West State Street
    Boise, ID 83703

13. Illinois Department of Transportation
    Director - Division of Highways
    Room # 300
    2300 S. Dirksen Parkway
    Springfield, IL 62764

14. Indiana Department of Transportation
    Chief Engineer
    100 North Senate Avenue
    Indianapolis, IN 46204

15. Iowa Department of Transportation
    Construction Engineer
    800 Lincoln Way
    Ames, IA 50010

16. Kentucky Transportation Cabinet
    Assistant State Highway Engineer for Construction
    10th Floor - State Office Building
    501 High Street
    Fankfort, KY 40622

17. Kansas Department of Transportation
    Bureau Chief of Construction and Maintenance
    8th Floor - Docking State Office Building
    Topeka, KS 66612

18. Louisiana Department of Transportation and Development
    Chief - Construction Division
    PO Box 94245
    Baton Rouge, LA 70804-9245

19. Maine Department of Transportation
    Engineer of Construction
    State House Station 16
    Augusta, ME 04333-0016

20. Maryland Department of Transportation
    Chief Engineer for State Highway Administration
    707 North Calvert Street
    Baltimore, MD 21201

United States Distribution List for the North American Survey (continued)

21. Massachusetts Highway Department
Chief Engineer
10 Park Plaza
Boston, MA 02116

22. Michigan Department of Transportation
Engineer of Construction - Construction Division
PO Box 30050
Lansing, MI 48909

23. Minnesota Department of Transportation
Construction Engineer - Office of Construction
MS 650 - Transportation Building
St. Paul, MN 55115

24. Mississippi Department of Transportation
Deputy Director of Pre-Construction
PO Box 1850
Jackson, MS 39215-1850

25. Missouri Highway and Transportation Department
Division Engineer of Construction
PO Box 270
Jefferson City, MO 65102

26. Montana Department of Transportation
Acting Construction Engineer
2701 Prospect Avenue
Helena, MT 59620

27. Nebraska Department of Roads
Construction Engineer
PO Box 94759
Lincoln, NE 68509

28. Nevada Department of Transportation
Chief Construction Engineer
1263 S. Stewart Street
Carson City, NV 89712

29. New Hampshire Department of Transportation
Department Head of Construction
1 Hazen Drive
Concord, NH 03302-0483

30. New Jersey Department of Transportation
Executive Director of Regional Operations (Region 5)
1035 Parkway Avenue
Trenton, NJ 08625

United States Distribution List for the North American Survey (continued)

31. New Mexico State Highway and Transportation Department
    Division Director - Design and Construction
    PO Box 1149
    South Building # 4
    Santa Fe, NM 87504-1149

32. New York Department of Transportation
    Deputy Chief Engineer - Construction Division
    Building # 4 - Room # 101
    1220 Washington Avenue
    Albany, NY 12232

33. North Carolina Department of Transportation
    State Highway Construction and Materials Engineer
    PO Box 25201
    Raleigh, NC 27611

34. North Dakota Department of Transportation
    Construction Engineer
    608 East Boulevard Avenue
    Bismarck, ND 58505-0700

35. Ohio Department of Transportation
    Engineer of Construction
    25 South Front Street - Room # 404
    Columbus, OH 43216

36. Oklahoma Department of Transportation
    Assistant Director - Operations
    200 N.E. 21st Street
    Oklahoma City, OK 73105

37. Oregon Department of Transportation
    Manager - Operations Section
    800 Airport Road S.E.
    Salem, OR 97310

38. Pennsylvania Department of Transportation
    Deputy Secretary for Highway Administration
    Transportation and Safety Building - Room # 1200
    Harrisburg, PA 17120

39. Rhode Island Department of Transportation
    Chief Engineer of Transportation
    2 Capitol Hill
    Providence, RI 02903

40. South Carolina Department of Transportation
    Director of Construction
    PO Box 1912 Capitol Hill
    Columbia, SC 29202

United States Distribution List for the North American Survey (continued)

41. South Dakota Department of Transportation
Construction Engineer
700 Broadway Avenue East
Pierre, SD 57501

42. Tennessee Department of Transportation
Executive Director - Bureau of Operations
James K. Polk Building - Suite # 700
Nashville, TN 37243

43. Texas Department of Transportation
Assistant Executive Director for Field Operations
125 East 11th
Austin, TX 78701-2483

44. Engineer for Construction
Construction Division
Utah Department of Transportation
4501 South 2700 West
Salt Lake City, UT 84119

45. Vermont Agency of Transportation
Director of Construction and Maintenance
133 State Street
Montpelier, VT 05633

46. Virginia Department of Transportation
Construction Engineer
1401 East Broad Street
Richmond, VA 23219

47. Washington State Department of Transportation
Chief Construction Engineer
PO Box 47354
Olympia, WA 98504-7354

48. West Virginia Department of Transportation
Chief Engineer - Operations
1900 Kanawha Boulevard East
Building # 5 - State Capitol Complex
Charleston, WV 25305

49. Wisconsin Department of Transportation
Director - Office of Construction
Construction Room # 601
PO Box 7916
Madison, WI 53707-7916

50. Wyoming Department of Transportation
State Construction and Maintenance Engineer
PO Box 1708
Cheyenne, WY 82002-9019

Canada Distribution List for the North American Survey

1. Alberta Department of Transportation and Utilities
   Assistant Deputy Minister of Regional Operations
   4999 98th Avenue
   Edmonton, Alberta, Canada T6B 2X3

2. British Columbia Ministry of Transportation and Highways
   Chief Highway Engineer
   940 Blanshard Street
   Victoria, British Columbia, Canada V8W 3E6

3. Manitoba Department of Highways and Transportation
   Assistant Deputy Minister
   215 Garry Street, 16th Floor
   Winnipeg, Manitoba, Canada R3C 3Z1

4. New Brunswick Department of Transportation
   Director of Construction
   PO Box 6000
   Fredericton, N.B., Canada E3B 5H1

5. Newfoundland Department of Works, Services and Transportation
   Construction Engineer
   PO Box 8700
   St. John's, Newfoundland, Canada A1B 4J6

6. Commonwealth of the Northern Mariana Islands
   Office of the Director of Public Works
   Saipan, CM 96950

7. Northwest Territories Department of Transportation
   Head - Design Services
   Box 1320
   Yellowknife, N.W.T., Canada X1A 2L9

8. Nova Scotia Department of Transportation and Communications
   Director of Construction
   PO Box 186
   Halifax, Nova Scotia, Canada B3J 2N2

9. Ontario Ministry of Transportation
   Manager - Contract Management Office
   1201 Wilson Avenue - 2nd Floor, West Building
   Downsview, Ontario, Canada M3M 1J8

10. Quebec Ministry of Transportation
    Executive Director - Construction Branch
    700 East Street Cyrille Boulevard - 28th Floor
    Quebec City, Canada G1R 5H1

11. Saskatchewan Highway and Transportation Department
    Assistant Deputy Minister of Operations
    1855 Victoria Avenue
    Regina, Saskatchewan, Canada S4P 3V5

District Office Distribution List for the Florida Survey

1. District Construction Engineer (District # 1)
   Florida Department of Transportation
   PO Box 1249
   Bartow, FL 33830-1249

2. District Contract Compliance Officer
   & Construction Utility Engineer (District # 2)
   Florida Department of Transportation
   PO Box 6669
   Jacksonville, FL 32236-6669

3. District Construction Engineer (District # 2)
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   PO Box 1089
   Lake City, FL 32055-1089

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5. District Construction Engineer (District # 3)
   Florida Department of Transportation
   PO Box 607
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6. District Construction Engineer (District # 4)
   Florida Department of Transportation
   3400 West Commercial Boulevard
   Fort Lauderdale, FL 33309

7. District Construction Engineer (District # 5)
   Florida Department of Transportation
   719 South Woodland Boulevard - MS 3-506
   Deland, FL 32720-6800

8. District Construction Engineer (District # 6)
   Florida Department of Transportation
   1000 NW 111th Avenue
   Miami, FL 33172

9. District Construction Engineer (District # 7)
   District # 7
   Florida Department of Transportation
   11201 N. McKinley Drive - MS 7-1100
   Tampa, FL 33612

10. Turnpike Construction Engineer (The Florida Turnpike Authority)
    Florida Department of Transportation
    PO Box 17870
    Plantation, FL 33318-7870

APPENDIX C
CALIFORNIA DOT HIGHWAY CONSTRUCTION CHECKLIST

HIGHWAY CONSTRUCTION CHECKLIST

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

1985

FOREWORD

This checklist is a revision of the 1971 issue.

This edition is not intended to be a substitute for any other publication of the Department. It is to be used as a guide to engineering judgement. As such, it will be of value to the experienced field engineer as a reminder; it will be valuable to the inexperienced person as a training aid and a checklist to assure that contract administration is being performed adequately.

The California Department of Transportation has an enviable reputation for the administration of its program and the quality of its finished product. This booklet is designed to serve as an aid not only in maintaining that reputation but in improving it.

Leo J. Trombatore

Leo J. Trombatore
Director, Department of Transportation

CONTENTS

CONCRETE STRUCTURES

REFERENCES

Standard Specifications, Sections 51, 52, 90

Construction Manual, Sections 6-51, 6-52, 6-90

Portland Cement Concrete - Production Operations, this Checklist

ACTIVITIES BEFORE CONSTRUCTION

Review structure locations - compatibility with planned locations, existing conditions, utilities; ready for stakes (rough graded)

Prepare 4-scale drawings (major bridge structures) - falsework, abutment, bent, deck and rail grades

Obtain contractor's "Request For Construction Staking" - order stakes

Check engineer's stakes - lines, offsets, references, elevations, grades, adequate for quantity measurements, conform with existing curbs, inlets, pavement; review with contractor

Review contractor's progress schedule - compatibility with water pollution control plan

Obtain contractor's falsework drawings, design calculations, contractor's certificate for use of manufactured assemblies (when used) - advise contractor when approved

Obtain contractor's trench shoring and sloping data - advise contractor when approved; remind him of DOSH excavation permit requirement

Determine whether the contractor has submitted prestress working drawings - advise contractor when approved (obtain microfilms at end of job)

Ensure that railroad insurance is in order (Const. Man. 2-07)

Review the contractor's code of safe practices and accident prevention program

Report impaired clearances - notify district office, local agencies

Obtain the Notice of Materials To Be Used, HC-30 - review, send to Translab

Obtain initial samples, tests (see Portland Cement Concrete-Production Operations, of this Checklist)

Look for potential overloads - increase structural capacity

Examine forming system - request data on design and materials (if necessary)

Examine pile driving equipment - proper types, capacities, other specified attributes

ACTIVITIES DURING CONSTRUCTION

Safety

Review lane closures - advise maintenance, local agencies, CHP

Be safety conscious

Observe operations - comply with code of safe practices; hardhats worn, work areas clean, railings in place, ladders used properly, scaffolding O.K., overhead wires noted, safety belts used, proper clothing worn, safety meetings

Note imminent hazards, dangerous conditions - discuss with contractor, take action (Const. Man. 1-60)

Excavations, Foundations

Observe excavations - sloping, shoring as required

Examine foundations - firm, stable, adequate bearing capacity (field test as necessary)

Piling

Ensure predrilling of holes for piling to be driven through new embankments - proper diameter, proper filling after driving

Examine pile driving equipment - proper hammer for type of piling

Check for required driving heads - no damage to piling, use of cushion blocks

- Check for proper restraint from lateral movement during driving of piling
- Ensure that precast concrete piles are not driven until 14 days after casting; timber piles driven within 6 months after treatment
- Examine piling - proper evidence of inspection, no damage during shipment
- Maintain "Pile Quantity & Driving Record" and "Log Record" (or "Drilling Record") - calculate blow count, check specified tip; observe placement of reinforcing and concrete
- Perform load tests - maintain records for payment
- Ensure that steel pile splicing is performed as specified - welder qualified
- Check holes for cast-in-place concrete piles - proper dimensions, alignment, de-watering

Falsework and Forms

- Observe falsework construction - compliance with DOSH Section 1717, continous inspection during erection, during and after concrete pour; proper member location and quality, adequate foundation
- Examine form material - rigidity, smoothness, cleanliness, proper grade of plywood
- Observe placement - mortar-tight, braced, provision for utilities; proper dimensions, lines, grades; triangular fillets in place, weep holes in, forms oiled, expansion joints and joint keys provided
- Ensure proper placement of electrical facilities, drainage features, cathodic protection, falsework supports

Reinforcing

- Obtain certificates of compliance

- Check wire mesh - wire size, mesh size
- Examine bars - proper grade, free of grease, excessive rust or scale; proper hook dimensions, no kinks or cracks
- Observe placement - compare with plans; proper size and shape, spacing, length, clearance; securely held in place; chairs, anchors, spacers, stirrups, wiring
- Ensure proper splicing - wired laps, welding, mechanical; properly staggered
- Consult with Translab for splice testing, certification of welders
- Maintain Bar Reinforcing Steel Placing Record, DS-C76 (major structures)

Prestressing

- Check placement of ducts for prestressing steel - proper material, placement, clearances, mortar-tight, securely fastened; vents of proper size and located as specified
- Examine prestressing steel - properly packaged, free of excessive rust or other damage, required evidence of inspection (TL624 or other markings)
- Obtain contractor's jack data, calibration charts
- Calculate required elongation of prestress steel - adequate concrete strength before stressing
- Observe prestressing - proper sequence and loading
- Observe grouting - check for proper material, grout efflux time; valves installed and operated as specified

Placing Concrete

- Examine forms and reinforcing - clean up chips, sawdust, foreign matter; dewater
- Ensure proper construction joints - sandblasted, moistened
- Check ambient and/or concrete temperatures - availability of protective devices

Ensure that embedded fixtures are in place - anchor bolts, pipes, sleeves, metal inserts, weep holes, drains, electrical, restrainer components

Establish communication with concrete production facility

Ensure that compressive strength concrete is prequalified, production and materials in accordance with pre-qualification

Obtain load slips for ready-mixed concrete - check mixer revolutions, time limits, cement content

Observe concrete placement - no retempering; proper use of pipes, tubes, belts; no excessive drops, no segregation; adequate vibration within time limit, proper sequence for vertical and horizontal members; tremie for underwater placement

Sample concrete - test for temperature, penetration, air content, yield, cement factor; fabricate test cylinders, identify, cure and store properly; send to lab with required paperwork

Observe curing method - forms in place, exposed surfaces moist continuously or curing compound applied; proper curing material

Ensure that forms and/or falsework remain in place as specified - length of time, results of compressive strength tests, prestressing steel tensioned

Measure surface of bridge decks - within straightedge tolerance, profilograph, surface crack intensity, coefficient of friction

Ensure proper sequence of falsework removal - adequate protection for public traffic (detour if necessary)

Check surface finishing, ordinary, Class 1, Class 2 - holes filled, rock pockets repaired, fins removed, matching

color, uniform texture

Maintain Concrete Pour Record, DS-C73 (major structures)

Joint Seals

Observe installation - proper methods, proper materials and workmanship

RECORDS

Include in the Asst. Res. Engrs. Daily Report (HC-10A)

- Instructions and/or significant discussions with contractor
- Notes on your inspections
- Hours worked by personnel and equipment
- Records for force account payment

Measure and/or calculate quantities - complete Structure Summary HC-53; (minor structures); complete Quantity Calc. Sheet HC-52

Retain/file

Certificates of compliance, load tickets, inspection tags, test reports

Report of Completion (Structures) - include list of materials, quantities, costs, utility report, joint seal report, paint records

Deck protection reports

Railroad Reports

Microfilms of shop drawings

As built plans

APPENDIX D
TRB CONSTRUCTION MANAGEMENT COMMITTEE SURVEY

COLLEGE OF ENGINEERING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA 32611
DEPARTMENT CHAIRMAN
AREA CODE 904 PHONE 392-6537
STUDENT RECORDS
AREA CODE 904 PHONE 392-0933

DEPARTMENT OF CIVIL ENGINEERING

Date:

Respondent's Name
Respondent's Title
Respondent's Organization
Address of Organization

RE: Knowledge Acquisition and Experience Capture

Dear Respondent's Name:

The Florida Department of Transportation, like many other state highway agencies, is facing a major problem of losing the acquired knowledge of veteran employees who leave the department through retirement, change of jobs, or for a variety of other reasons. These employees possess the equivalent of hundreds of years of accumulated experience, and if their expertise is not somehow collected and transferred, this valuable source of information will be lost forever. This predicament is especially acute in the realm of construction operations, where frequently the experience is not documented in any written form and usually kept only as personal knowledge.

The University of Florida is conducting research with the goal of developing a systematic procedure for gathering construction knowledge and experience, organizing this data, and storing it for future use. *Our purpose for contacting you is to ask if you know of any similar efforts either within your own organization or elsewhere. We are very interested in any information, documentation or computer software that you may have or are aware of concerning this topic*.

We realize that a response to our request will require your time and effort, and we fully understand the demands already placed upon your time. However, we feel that your participation is vital, and our study would be significantly deficient without your participation. Upon completion of our research and publication of our findings, we will gladly forward you a copy of our report for your use.

Thank you in advance for all your cooperation, it will be greatly appreciated. We look forward to hearing from you and encourage you to contact us anytime to discuss any ideas you may have regarding this study.

Please send any pertinent information to:

Dr. Zohar Herbsman
University of Florida
Department of Civil Engineering
345 Weil Hall
Gainesville, FL 32611-2083
Telephone: (904) 392-0935
FAX: (904) 392-3394
E Mail: ZOHAR@CE.UFL.EDU

Sincerely,

Dr. Zohar Herbsman

Distribution List for the TRB Letter of Inquiry

1. Arizona Department of Transportation
   Deputy Director
   206 S. 17th Avenue, Room 101A
   Phoenix, AR 85007

2. Ballenger Paving Company, Inc.
   President
   Post Office Box 127
   Greenville, SC 29602

3. Bechtel Parsons Brinckerhoff
   Project Manager
   One South Station
   Boston, MA 02110

4. Bergstralh-Shaw-Newman, Inc.
   Senior Vice President
   5300 Westview Drive, Suite 107
   Frederick, MD 21701

5. Federal Highway Administration
   Highway Engineer, C&M Division
   HNG-21, Room 3211
   400 Seventh Street S.W.
   Washington, D.C. 20590

6. Kansas Department of Transportation
   CPMS Administrator
   10th and Topeka
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   Topeka, KS 66612

7. L.A. County Metropolitian Transp. Authority
   Section Manager - Engineering
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   Los Angeles, CA 90017

8. Martin L. Cawley & Associates
   Consultant
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   Glenview, IL 60025-1151

9. Micheal Baker Jr., Inc.
   Vice President
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   420 Rouser Road
   Coraopolis, PA 15108

Distribution List for the TRB Letter of Inquiry (continued)

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    Construction and Maintenance
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13. North Carolina Department of Transportation
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    Highway Building, P.O. Box 25201
    Raliegh, NC 27611

14. Norway Public Roads Administration
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    Post Office Box 6390-Etterstad
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15. Orin Riley, P.E., P.C.
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    80 Wall Street, Suite 1016
    New York, NY 10005-3602

16. Parsons Brinckerhoff Construction Services, Inc.
    President
    475 Spring Park Place, Suite 500
    Herndon, VA 22070

17. Richard Felsinger International
    President
    Triesterstre 2-40
    Post Office Box 206
    A-2500 Baden, Austria

18. Transportation Research Board
    National Research Council
    Engineer of Materials and Construction
    2101 Constitution Avenue, N.W.
    Washington, D.C. 20418

APPENDIX E
TWO REPRESENTATIVE RESPONSES TO THE TRB SURVEY

Parsons
Brinckerhoff

January 5, 1995

Dr. Zohar J. Herbsman
UNIVERSITY OF FLORIDA
Department of Civil Engineering
345 Weil Hall
Gainesville, FL 32611-2083

Re: Knowledge Acquisition and Experience Capture

Dear Dr. Herbsman:

With regards to your letter dated December 1, 1994, you are accurate in your assessment of the tremendous loss any construction organization feels when a veteran employee leaves the firm. Parsons Brinckerhoff Construction Services, Inc. (PBCS) faces this same scenario.

PBCS has strived to educate and train each of our own employees at a considerable price in every avenue of construction through nationally recognized organizations such as ATSSA, ACI, Troxler and NICET.

PBCS takes great pride in placing qualified employees on every project knowing that each individual has the multiple certifications and experience necessary to complete any task required by our clients.

At this time we do not posses any way of gathering and documenting the construction knowledge and experience obtained by our own employees. However, we would be very interested to review any of your findings or recommendations on this issue.

Sincerely,

PARSONS BRINCKERHOFF CONSTRUCTION SERVICES, INC.

Christopher E. Reseigh, PE
President

CER/glh

MARTIN L. CAWLEY
2330 Greenwood Road
Glenview, Illinois 60025
(708) 272-2392
(708) 272-2393 Fax

December 16, 1994

Dr. Zohar J. Herbsman
U of Florida, Dept. of Civil Engineering
345 Weil Hall
Gainsville, FL 32611-2083

Dear Dr. Herbsman: Fax (904) 392 3394

Re; Your ltr DEC 1, 1994-Knowledge recapture DOT / Civil Experience

During the past 35 years I have been involved in following the progress and development of Concrete Pavements while employed by the Corps of Engineers, Officer in the Navy CEC, Sr. Airfield Engineer for the PCA, Director and VP of the CRSI, and as a Pavement Consultant and Program Manager for multi-billion dollar development programs at Chicago's O'Hare, Newark,and Cincinnati International airports during the last decade.

I will briefly share some observations drawn over a reasonably long period of time, relative to continuity of management and perpetuation of technical knowledge. I was fortunate to have had a career that enabled me to progressively grow in each position and travel widely throughout the U.S. and Canada, during the heyday of the Interstate Highway construction and boom of the 60-70's in aviation and airport expansion. During those years most young engineers had opportunities to enter formalized training programs and to understudy well trained and experienced engineers who knew their profession. In recent years the mobility, transient work and shortened time in positions have led to less documentation and carryover of skills./ The emphasis has been on *document for legal purposes* rather than building a reservoir of solid knowledge of do's and don'ts. One only has to look at the emphasis of publish or perish in the quality and theoretical nature of papers submitted to the TRB each year. There is less and less improvement and too obvious a re-inventing the wheel because prior experience was not tapped. Shoddily done , or literature searches which tend to perpetuate one narrow school of thought, or lack of effort in bibliography development illustrates that practical experience is not being documented or modern computer retrieval files don't get the right input. The cause may be that organizations like the PCA, AI, and myriad of other industry trade associations no longer have the financial support nor staffs to record and publish the technical progress that is made.

For years the Europeans, and other emerging nations have looked to the U.S. and our associations as the experts for knowledge, but that is becoming less the case–as these very industries like cement, oil, and steel have foreign ownership in our country. The cost of gaining knowledge is becoming very expensive, and sorting through the maze of information gathered in the technical libraries still requires separating the *tried and true* from the impractical, theoretical or long proven failed methods that keep resurfacing for who knows why?

Another factor has been the politicizing of the engineering industry in the public sector, and the obvious impacts environmental and social concerns have had on project accomplishment. By the time a project is completed the staff has changed and no one is around to close it out who knew why it got planned the way it did, designed the way it did, changed the way it did, and built the way it did! The marketing and legal documentation survive but the engineers involved in making the project happen don't have or take the time to record history, and they are on to the next job or assignment in a new organization. A case of the old cliché' the *hurrier we go the behinder we get.*

One suggestion I have for large projects is to require a summary report from the design and construction project managers outlining the unique or unusual features of the project, or those lessons learned to make the next go - around easier. Obviously such a report would be limited to the experience of those who have a clear and comprehensive perspective after completion, but a properly designed questionnaire for various types of projects might prove valuable to those charged with undertaking the next similar project.

Frankly there is a wealth of information that can be gleaned if time is allocated at the outset to explore state of the art publications in the technical trade press, from associations, by networking with other airport, highway department, and consulting engineers through local, regional and national organizations and committees. The trend of States toward requiring continuing education and Professional Development Hours to maintain PE licenses will encourage individuals to attend more seminars where technical information is exchanged outside the day to day routine of business. This interchange will improve technology transfer but not necessarily preserve the knowledge within the individuals organization. There must be a conscious effort on the part of management and clients to capture the right knowledge, and not just archive it; the format for retrieval is the key to computerized systems. If the effort required is too complex and laborious-it won't get the input that is worth preserving.

I trust my thoughts and comments may be helpful in your very challenging task.

Very truly yours,

Martin L. Cawley, P.E.

APPENDIX F
NEW YORK DOT CONSTRUCTION SUPERVISION MANUAL

Construction Supervision Manual

CONSTRUCTION DIVISION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
MARIO M. CUOMO, Governor JOHN C. EGAN, Commissioner

NEW YORK STATE

DEPARTMENT OF TRANSPORTATION

CONSTRUCTION SUPERVISION MANUAL

FOREWORD

This manual is designed to provide guidance and establish uniform procedures to be followed in the supervision and inspection of projects under construction by contract with the New York State Department of Transportation.

This manual provides a ready reference to administrative policies of the Department related to highway construction. All personnel of the Department and consultant forces involved in any phase of the contract administration should refer to this manual for guidance in the performance of their duties

This manual was prepared in loose-leaf format to permit ready updating. The holder of the manual is responsible for inserting all additions and revisions as they are issued. Any errata noted should be brought to the attention of the Construction Division.

550 STRUCTURAL DECK INSPECTION GUIDE

Adequate supervision of bridge deck construction is critical to insure a safe and durable product, particularly in view of its high cost for construction and maintenance. The following inspection guide has been reviewed with Main Office Structures and Materials staff and should be studied carefully by the EIC and his inspectors well in advance of the work.

POINTS TO LOOK FOR WHEN INSPECTING THE PLACING, FINISHING AND CURING OF INTEGRAL WEARING COURSE BRIDGE DECKS

(A Do's and Don'ts List)

A properly constructed bridge deck should be durable, safe, and ride well. This means it should be of the best quality construction, true to line and grade, ride smoothly, and have the proper surface texture so that it will perform its intended function in proper fashion throughout its intended life with little or no maintenance. This is a "tall order" for any structure and requires careful attention to detail throughout the design and construction phases. The construction phase is even more demanding when integral wearing course design is used because with it you only get one chance. Both the triumphs and the errors remain for all to see and feel during the useful life of the structure.

Some of the more common failings of our integral wearing course bridge decks have been cracking, spalling, rough ride (both short bumps and long ones), and relatively slick or slippery surface. These can be minimized or eliminated by following proper construction practices and procedures. Accordingly, there follows a list of some of the many practices and procedures that should be followed or avoided, as the case may be, in the placing, finishing, and curing of integral wearing course bridge decks. They have been grouped as follows:

I - General

II - Structural Steel Operations

III - Forming Operations

IV - Reinforcing Steel Operations

V - Bridge Finishing Machine Preparation

VI - Concrete Operations

A. Prior to Placing Concrete

B. Placing Concrete

C. Finishing Concrete

D. Curing of Concrete

E. Transverse Sawcut Grooving of Structural Slab Surfaces

550 STRUCTURAL DECK INSPECTION GUIDE (continued)

I GENERAL

All operations in the construction of a bridge deck have their effect on the final product but TWO of the MOST CRITICAL FACTORS on the durability of the structure are the PROPER CONCRETE AIR ENTRAINMENT and the PROPER CONCRETE COVER OVER THE REINFORCING STEEL. Be sure that the contractor and his material supplier understand that the specifications and Materials Method 9.2 will be followed to the letter. Be equally sure that the contractor places his reinforcing steel according to the plans and adequately ties and anchors it in accordance with the specifications, so that it will remain in that location throughout the concreting operations. It should be physically restrained from floating in the plastic concrete. The placement of concrete shall not be allowed if the above conditions are not met.

A. Proper planning should be undertaken by both the contractor and the inspection force in advance of actual construction. Such planning should include a job meeting to discuss in detail the equipment and procedures that will be employed by the contractor. A major point of discussion should be the provision of adequate delivery of concrete and sufficient placing equipment to insure that the placement can be accomplished in sufficient time to avoid concrete set prior to completion of finishing operations.

   In addition, agreement should be reached on contingency plans to handle unanticipated equipment breakdowns or interruptions in concrete supply.

B. As an engineer or inspector, make sure that you are completely familiar with the specifications for the work, including any special specifications, special notes, addenda to the specifications, appropriate Materials Methods, and all related information.

II STRUCTURAL STEEL OPERATIONS AS RELATED TO PLACING, FINISHING AND CURING

A. The specifications and the Steel Construction Manual should be reviewed.

B. Approved shop drawings for the structural steel should be studied and the fabricated members checked for conformance to them. Particular attention should be paid to proper camber. Be alert for out of tolerance sweeps, bends, or twists in the members both before and after they are in their final position and bolted up.

C. Studs or other types of shear connectors should be checked for correct size. Spacing and weld quality should be checked during installation.

D. Plans for steel bridges contain the following note: "No welding shall be allowed within the tension zones shown, unless specifically noted. The attachment of forming devices or other construction aids by welding within the tension areas shown is prohibited."

   Plans for continuous steel bridges (those having top flange tension zones) will have the tension zones defined. The tension zone areas are the areas in which no welding, other than that shown on the plans, will be allowed. Stud Shear Connectors may be continued through

550 STRUCTURAL DECK INSPECTION GUIDE (continued)

areas to approximately the point of D.L. contraflexure, which will also be shown on the plans. Stud Shear Connectors shall not be continuous across these tension zone areas.

Only welding for the purpose of repairing a steel stringer will be allowed in a tension zone, and this welding will only be allowed in conjunction with a repair procedure approved by the Deputy Chief Engineer, Structures.

If the plans for any bridge being constructed under your direction appear ambiguous or incomplete with regard to the definition of the tension zone, contact the Structures Division for clarification or interpretation of the plans.

Failure to comply with this requirement may lead to serious fatigue cracking of steel stringers and resultant shortened bridge life and/or high repair costs.

III FORMING OPERATIONS AS RELATED TO PLACING, FINISHING AND CURING

A. Forms should be adequate to support the loads to be applied and they should be properly supported. Minor movements in forms or brackets can cause an unacceptable change in dimension "X" in Figure 1. The stability of dimension "X" is essential to the final riding quality and rebar cover of the finished deck. The forms are the contractor's responsibility but you should be alert to any obvious weaknesses in the installation and call them to his attention. Other problem points are shown in Figure 1.

The Engineer should compare commercially manufactured support system installations for conformance to the manufacturer's recommendations. Other support systems should be checked for good workmanship in accordance with Figure 1.

B. Make sure that you and the contractor are in agreement on haunch depths before setting forms. This is especially critical on stay-in-place forms since the support angles which control the haunch depth are permanently welded to the beams, see II-D. Check and record haunch depths after installation of forms.

C. When stay-in-place forms are used, be sure the direction of lap in the forms is correct relative to the direction of concrete placement (See VI-A.2). The form section being loaded with concrete should lap over the unloaded section of form just ahead in order to prevent separation of the two sections.

D. At bridge joints, the forms at the end of the deck slab must be supported solely on the superstructure steel for the span being formed. There should be no formwork support or connection across a joint betw-en independent spans or between an abutment and the span. This allows the joint forms to move with the top of the girders through dead load application and any temperature movement that may occur.

E. Drill weeps in corrugated metal form joints as required by the specifications.

550 STRUCTURAL DECK INSPECTION GUIDE (continued)

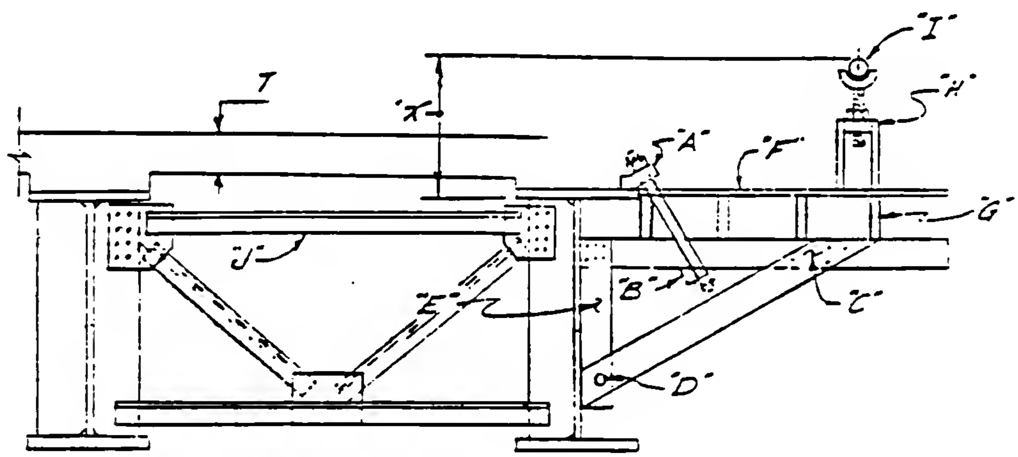

Figure No. I

x = Top Flange Thickness + Haunch Depth + Deck Thickness + Rail Height.

A = Hanger on beam (No weld in tension area.)
B = Washer or nut worn.
C = Joints not properly nailed.
D = Pin or holes worn.
E = Bracket not seated on beam.
F = Warped form.
G = Warped stringer.
H = Pipe bracket not seated.
I = Pipe or rail bent.
J = No top diaphragm strut in bay adjacent.
T = Nominal concrete slab thickness.

550 STRUCTURAL DECK INSPECTION GUIDE (continued)

IV REINFORCING STEEL OPERATIONS AS RELATED TO PLACING, FINISHING AND CURING

A. Reinforcing bars should be properly handled, stored and installed. Proper bar spacing should be maintained both horizontally and vertically. This means that all straight bars must be reasonably straight. Bars should be free of loose scale, grease, dirt and mortar.

B. Use only appropriate chairs to support reinforcing steel. They should be of the proper height to provide the correct bar spacing, clearance and cover. They should be used in sufficient numbers to insure adequate and proper support, and to insure that proper clearance and spacing will be maintained when concrete is placed. Bar mats should not sag excessively when walked on by workmen and inspectors. Remember that at least four or five workmen will be standing on the bar mat during placement operations. Make sure the reinforcing steel is adequately secured to insure that it will follow the forms as the camber comes out of the beams, thereby insuring the proper cover on the bars. This is especially important in the area of maximum dead load camber (mid-span for simple beams). Mats shall be tied together and may be tied to forms and/or structural steel or shear studs to achieve the above results.

C. Make sure that bars are supported at transverse joints so they will not flex down into the end haunch area when walked upon. A plywood walkway placed over the reinforcing steel at joints and heavy traffic areas will prevent excessive sag. Chairs should be placed at points of slope change.

D. Make sure that plan clearances are maintained between bars, joint assemblies and side forms.

V BRIDGE FINISHING MACHINE PREPARATION

A. Make sure that the finishing machine is approved by the Deputy Chief Engineer (Structures) and that it is in satisfactory operating condition.

B. Obtain a copy of the operating instructions for the finishing machine and become familiar with it before making the dry run. It is the contractor's responsibility to adjust and operate the machine but inspector familiarization can be beneficial.

C. Remember that screed rail positioning and support is one of the critical factors in deck construction. Rails should not sag or wobble under the weight or action of the finishing machine. Use the recommended screed rail support spacing as shown in the manufacturer's manual.

D. If screed rails are to be supported on the fascia forms, bracing should be supplied to properly resist both the deflection under the load of the finishing machine and the lateral movement caused by the oscillation of the machine. Check "X" distance (See Figure 1) before, during, and after the dry run of the machine.

550 STRUCTURAL DECK INSPECTION GUIDE (continued)

E. The longitudinal wheelbase of the finishing machine must be considered when adjusting screed rails on multi-span structures. In setting the rails, take into account the fact that, with a long wheelbase finishing machine, one end will be on the adjacent unloaded span while the other end will be on the loaded span (where the dead load camber has or will come out) as you load the end of the span with fresh concrete.

F. In setting up the finishing machine and making the dry run be sure you take into account possible differences in dead load deflection characteristics between the fascia girders and interior girders. This is particularly important for deck replacements. It is recommended that finishing machines be oriented parallel to the skew angle up to skews of 35°. For greater skew angles, the machine should be operated at a skew angle of 35°.

G. Check clearances in a dry run over the entire span to be paved the day before the placement. It is recommended that the adjustment controls be locked or sealed in some manner so they will not be altered before placement begins. Some last minute clearance checks just before placing may be good insurance and reassuring to all involved. If it is necessary to raise the machine to back it off the span after the dry run, record this change so that the machine can be reset when moved back on the span for finishing.

H. If the finishing machine has hydraulically operated actions, take care to see that they do not leak fluid onto or into the concrete. The machine should be monitored for hydraulic fluid leaks throughout the placing and finishing operations as well. The same holds true for grease or fuel that may drip onto or into the concrete. See that gobs of excess grease are removed before they get into the concrete.

APPENDIX G
U.S. ARMY CORPS OF ENGINEERS INSPECTOR'S GUIDE

EP 415-1-261
Volume 2
May 1986

US Army Corps of Engineers
Office of the Chief of Engineers

Construction Inspector's Guide

Pile Driving, Dams, Levees and Related Items

DEPARTMENT OF THE ARMY
U. S. Army Corps of Engineers
Washington, D. C. 20314-1000

EP 415-1-261

DAEN-ECC-Q

Pamphlet
No. 415-1-261

16 June 1986

Construction

CONSTRUCTION INSPECTOR'S GUIDE

FOREWORD

This guide is one of four volumes reprinted with revisions from guides first published in 1964. The reason for their existence and continuance is to provide for construction quality assurance personnel, a reliable checklist type reference for each phase of construction.

Used as a reference and study document this guide will prove invaluable to quality assurance personnel in the types of construction covered herein. The guide will serve to refresh your memory and alert you to potential problems. It is not intended to replace contract plans and specifications, your experience, training, and common sense, but to supplement them.

Conscientious use of this guide will assist you in providing better quality assurance and, as a result, quality construction for our customers throughout the world.

FOR THE COMMANDER:

Arthur E. Williams

ARTHUR E. WILLIAMS
Colonel, Corps of Engineers
Chief of Staff

This Volume 2 of EP 415-1-261 supersedes EP 415-1-264, October 1970.

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Chapters numbered in the guides contain the same subject information as the numbered divisions in the specifications for both military and civil works construction projects. They are identified by specific volume as follows:

Chapter Number	Volume 1	Subject
1		General Requirements
2		Sitework: earthwork, underground utilities, paving, plantings, and railroads
2	Volume 2	
		Sitework (continued): piles, levees, dams, relief wells, drilling, lock and dam gates, penstocks, revetments, dredging, jetty, breakwater, and groin construction.
	Volume 3	
3		Concrete
4		Masonry
5		Metals
6		Wood and Plastics
7		Thermal & Moisture Protection
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CHAPTER 2G
PILE CONSTRUCTION
INDEX

CHAPTER 2G
PILE CONSTRUCTION

2G-01. GENERAL

Information contained in this chapter applies in general to pile driving on any project; specific information pertaining to a particular project should be obtained from your supervisor and from the plans and specifications. If a conflict exists between this chapter and the contract plans and specifications, the contract will govern.

2G-02. GENERAL REQUIREMENTS

a. Check use of pile, i.e., point bearing or friction.

b. Check whether piles are to be driven to refusal, a specified bearing or depth.

c. Check workmanship, materials, and line and grade of completed work.

d. Maintain all required records.

e. Reject unsatisfactory materials.

f. Check testing of materials.

(1) At source of supply

(2) On site

g. Checks Prior to Driving

(1) Check pile lengths required and bearing capacity of piles.

(2) Check borings to determine the driving resistances to be expected and types of material to be encountered.

(3) Check piles as delivered to site and mark piles which are not acceptable.

(4) Check piles for length and have lengths indicated on piles near top.

(5) Check piles made up for specific locations; have the pile location number painted on the pile.

(6) Check out pile driving equipment for size and condition. Check boiler inspection certificate and other safety requirements where steam or compressed air is used. Continue checking daily.

(7) Obtain and study the brochure printed by the pile hammer manufacturer pertaining to the hammer being used in order to learn of hammer capabilities and limitations.

(8) Check types of special piles and obtain the brochures or pamphlets put out by the manufacturers of these piles to become familiar with the methods of handling, inspecting and driving.

(9) Check for pile numbering plan. Enter in your report the order driven.

(10) Check that heads are flat and smooth and are normal to the longitudinal axis.

h. Checks During Driving

(1) Check care in handling piles, overdriving, hitting obstructions, driving out of plumb, retardation of stroke and sequence of driving.

(2) Check strata into which piles are driven and depths. Check against profile of borings.

(3) Check that records include type of pile, length used, type and size of hammer, manufacturer, strokes per minute, blows per foot, number of blows per inch of penetration, elevations of pile butt and tip after driving.

(4) Check that approval is obtained for relocation of piles or driving additional piles.

(5) Check the behavior of the pile during driving.

(a) Check hardness of driving at various depths against the strata shown on the boring log.

(b) Check for deviations which indicate broken piles, obstructions or driving irregularities. Check inside length against outside markings.

(6) Check steel driving shoes used on wood or concrete piles. Check damage to pile tip by pulling an occasional pile.

(7) Check that piles are driven continuously. If driving is suspended, note the tip grade at the time of the shutdown and the duration of the delay.

(8) Check uplift on piles.

(a) Check when piles are driven in groups or clusters for heaving of earth around the piles.

(b) Check grades on piles after they are driven and later rechecked.

(c) Check with your supervisor if heaving occurs.

(9) Check that use of small tips is avoided. Check damage to tips on wood piles by pulling an occasional pile.

(10) Check for preparation of pile schedule and lengths.

(a) Drive several piles adjacent to boring locations.

(b) Note blows per foot for each foot.

(c) Compare (b) with boring data.

(11) Check that piles are set vertically, or, if batter piles, on the axis which they are to follow. Check that the hammer is centered over the pile.

(12) Check use of templates or timber bracing for guiding piles when driving without leads.

(a) Check deviation from proper location. Cut off and abandon and drive new pile.

(b) Pull and redrive.

(13) Check jetting is used only with approval of supervisor.

(a) Check depth jetting permitted.

(b) Check for walking out of plumb and loosening of piles previously driven.

(c) Check piles are redriven after jetting in area is completed.

(d) Check possibility of damage to existing structures if jetting permitted.

(14) Check lagging is used only with prior approval.

(15) Check piles are not driven within 100 feet of concrete less than 7 days old.

(16) Check ownership and payment of pile cut-offs. Check if cut-off lenghts are excessive.

(17) Check your records indicate pay lengths.

(18) Check deviations from pile schedule; notify your supervisor.

(19) Check pile driving is not started until approval is secured as to the type and weight of the hammer to be used.

i. Site Conditions, Inspection of Equipment

(1) Check for unfavorable conditions such as rock, ledge, boulders not indicated on drawings, excessive soft spots, crusts, old foundations disclosed during construction, and report to your supervisor.

(2) Check site conditions, including lines, grades, foundation preparation, all available boring information, right-of-way, roadways, streams or other waterways, terrain, and all driving conditions.

(3) Check equipment proposed for use by the contractor will produce the finished work of required standards within the scheduled time.

(a) Check size of hammer.

(b) Check type of driving hammer bases, anvils and caps against type of piling.

(c) Check followers are used only with the approval of your supervisor.

(d) Check condition of hammer for wear, improper adjustment, poor lubrication, long hose lenghts, leaks and drops in steam pressure.

(e) Check double-acting and differential-acting hammers are run at manufacturer's rated speeds.

j. Pile Driving Procedure

(1) Check with supervisor procedure to be followed.

(2) Check formula to be used as a guide in determining bearing capacity.

(3) Check minimum bearing value to be obtained if not stated.

(4) Check with supervisor for blows per inch (or fraction of an inch penetration) for the last ten blows to be obtained when driving to refusal.

APPENDIX H
JACKSONVILLE CORPS OF ENGINEERS LESSONS LEARNED

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT CORPS OF ENGINEERS
P. O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

CESAJ-DD (1110-2-1150a) 2 December 1993

MEMORANDUM FOR Commander, South Atlantic Division, Atlanta, GA 30335-6801

SUBJECT: Cerrillos Dam Lessons Learned Report

1. The enclosed Cerrillos Dam Lessons Learned Report was prepared by the Cerrillos Lessons Learned Committee and is organized into five general categories; seepage through the foundation, leaks in the intake structure, instrumentation, organization, and safety. The Lessons Learned Committee initially developed the report by gathering input from team members involved in the planning, design, construction and operation of the Cerrillos Dam Project. The report was further refined through several iterations to identify and consolidate key problems. These key problems are shown in the left column of the summary table for each category. Once the key problems were determined, the committee identified the lessons learned, a process to implement the lesson learned on the upcoming Portugues Dam, the action office that will insure the process is implemented, and the responsible disciplines involved. The action office has ownership and follow-up responsibility for assuring that each lesson learned is used on the Portugues Dam Project.

2. To assure a quality project is developed on the Portugues Dam, several actions have already been initiated. These actions include extensive coordination and review of the design with arch dam consultants, in-house partnering meetings between disciplines involved in the project, and trips to arch dams both in operation and under construction. Furthermore, a Portugues Action Group (PAG) is currently being organized. The need for the PAG was identified during a District partnering meeting and will be used to efficiently resolve technical issues that develop during the Portugues Dam construction.

3. We have initiated a quarterly review to monitor the status of pending actions identified in this report. This process will be initiated as a key addition to our project management plan for the Portugues Dam.

Encl

TERRENCE C. SALT
Colonel, Corps of Engineers
Commanding

CERRILLOS DAM LESSONS LEARNED
A. FOUNDATION SEEPAGE

LESSONS LEARNED ACTION GROUP
6 DEC 1993

PROBLEM	LESSON LEARNED	ACTION OFFICE	PROCESS TO IMPLEMENT	DISCIPLINE
A-01 Classification of the foundation and engineering properties was incomplete.	Conduct sufficient testing of the foundation rock to establish geological classification and engineering properties.	CESAJ-EN-G	a. For the Portugués Dam, the foundation has been extensively tested and geologically mapped. To date, there has been more testing at Portugues than at the Cerrillos site. More mapping and testing will be done during excavation contracts.	Design
A-02 Seepage quantities through foundation were greater than predicted by conventional analysis.	Use the latest and most advanced methods and tools to predict foundation seepage quantities.	CESAJ-EN-G	a. The Portugués Dam foundation has been analyzed for stability and seepage using state-of-the-art analysis techniques. After the foundation and test grouting program, the foundation will be reanalyzed using actual pressure tests permeability values in the 3-D finite element seepage model.	Design
	Available expertise from the Waterways Experiment Station (WES) should be sought early in the design process.	CESAJ-EN-G	b. WES will be tasked with the 3-D finite element seepage analysis. Scope of work will include analysis of different scenarios to validate the grouting program.	Design
A-03 Maintaining easily accessible and understandable data on testing and grouting was difficult.	An organized database, preferably computerized, for testing and grouting is required, during and after grouting.	CESAJ-EN-G CESAJ-CO	a. Set up and maintain a computerized database for grouting and testing. This will provide more timely information for necessary adjustments to the grouting plan. It will also allow a clear and organized documentation of the grouting records for current and future reference. The development of a database is currently in progress.	Design/ Contract Admin.

Final Review:

for Paul Shafer
Chief, Geotechnical Branch

for Edward E. Middleton, Ph.D., P.E.
Chief, Engineering Division

CERRILLOS DAM LESSONS LEARNED
B. CONCRETE LEAKS

LESSONS LEARNED ACTION GROUP
6 DEC 1993

PROBLEM	LESSON LEARNED	ACTION OFFICE	PROCESS TO IMPLEMENT	DISCIPLINE
B-01 Inadequate concrete consolidation.	Emphasis must be given to proper concrete consolidation to avoid leakage through the concrete. Lift joint preparation should be given special considerations. Special measures should also be used to assure consolidation in congested areas.	CESAJ-EN-D CESAJ-CO	a. Engineering and Construction will work with SAD Lab to assure workable concrete mixes. Final adjustment of the mixes will be made in the field using local processing of the aggregates, on-site batch plant, and in coordination with SAD Lab.	Design/ Contract Admin.
		Ditto.	b. Consolidation issues are to be resolved by the recently formed Portugués Action Group.	Ditto.
		Ditto.	c. The Portugués dam contract will include a concrete test placement (including a lift joint) to assure proper placement and consolidation methods are used. Coring and pressure testing will be incorporated into the test placement. The test placement and coring will provide training for government and contractor personnel as well as a means of adjusting the design concrete mixes.	Ditto.
		Ditto.	d. Coring and pressure testing will be incorporated into the Portugues dam contract to assure proper consolidation and lift joint bonding. Necessary changes to the coring and pressure testing procedures will be made as a result of above test placement.	Ditto.
		CESAJ-CO	e. Ensure QA/QC plans address and enforce lift thickness and consolidation requirements.	Contract Admin.
		CESAJ-CO	f. A contractor quality control (QC) representative will be required at the site during concrete operations.	Contract Admin.

		CESAJ-EN-D	g. A maximum size aggregate (MSA) concrete mix compatible with rebar spacing will be specified in the contract documents. MSA will be specified to assure proper consolidation in congested areas.	Design
		CESAJ-EN-D CESAJ-CO	h. Pumped concrete and other alternate placing methods will be specified in the contract documents where appropriate. These actions will be coordinated during the partnering process afforded by the Portugués Action Group.	Design/ Contract Admin.
	Special consideration should be given during placement of concrete against irregular foundation rock and existing lift surfaces.	CESAJ-EN-D	a. A small MSA concrete mix may be used on the initial pass to fill voids in the existing lift surface and to minimize rebounding and segregation of the large aggregate mix.	Design
		CESAJ-EN-D	b. A small MSA concrete mix will be specified on the initial leveling pass of the first lift off the foundation rock. This will minimize rebounding and segregation of the large aggregate mix.	Design
B-02 Failure to adequately inspect prior to placement.	Quality assurance personnel should assure that QC personnel are performing adequate inspections.	CESAJ-EN-D CESAJ-CO	a. Special emphasis will be placed on partnering, scheduling and coordination with the contractor to prevent or resolve problems during concrete placement.	Design/ Contract Admin.
B-03 Specific highly specialized expertise not available within the district.	Vast technical expertise is available throughout the Corps to assist in the resolution of complex engineering problems.	CESAJ-EN-D CESAJ-CO	a. PAG will develop a database of required specialized expertise applicable to design and construction of arch dams. This database will consist of resources available within USACE, USBR, etc.	Design/ Contract Admin

Final Review:

Don Carter
Don Carter
Chief, Design Branch

for
Edward E. Middleton, Ph.D., P.E.
Chief, Engineering Division

CERRILLOS DAM LESSONS LEARNED
C. INSTRUMENTATION

LESSONS LEARNED ACTION GROUP
6 DEC 1993

PROBLEM	LESSON LEARNED	ACTION OFFICE	PROCESS TO IMPLEMENT	DISCIPLINE
C-01 Instrumentation design was not well suited for automation.	When automation is to be used, a basic Instrumentation plan should be developed that satisfies the project requirements. Design of the Instrumentation program should follow the established plan.	CESAJ-EN-G	a. The automation concept will be developed jointly with the instrumentation design. Instrumentation Design Memorandum (DM-23) will address automation and instrument selection.	Design
C-02 Piezometers malfunctioned during and after construction.	Make sure that the instrumentation and associated equipment (i.e. riser pipes, couplings, etc) is properly designed for its intended application and is installed correctly.	CESAJ-EN-G CESAJ-CO	a. Same as above. In addition, purpose and goals of the instrumentation program will be adressed in the Engineering instructions to field personnel to assure a good understanding of the instrumentation program by those responsible for its installation and initial monitoring.	Design/ Contract Admin.
	Instrumentation design should accomodate the product of various suppliers. Sole sources of instrumentation devices should be avoided.	CESAJ-EN-G	b. Adequate flexibility will be incorporated in the instrumentation program to assure that various suppliers can be used to the maximum possible extent. Risers, etc. will be sized to accomodate several models of instrument. Riser pipes should be minimum 1" flush joint tubing. Slip joint casing should be of sufficient diameter to accomodate free movement of riser pipes.	Design
	Manufacturers/suppliers should be brought in early in the process in case of instrumentation malfunctioning.	CESAJ-EN-G CESAJ-CO	c. Instrumentation design will include a list of points of contact at the manufacturers/suppliers office to assure a quick response when and if the need arises. The District will be involved with the manufacturers/suppliers to the maximum possible extent.	Design

Final Review:

Don Carter
Chief, Design Branch

for

Paul Shafer
Chief, Geotechnical Branch

for

Alex Morrison
Chief, Construction Branch

CERRILLOS DAM LESSONS LEARNED
D. SAFETY

LESSONS LEARNED ACTION GROUP
6 DEC 1993

PROBLEM	LESSON LEARNED	ACTION OFFICE	PROCESS TO IMPLEMENT	DISCIPLINE
D-01 Contractor's safety plan and COE safety management ineffective (numerous fatalities)	Poor communication and enforcement reduces effectiveness of safety requirements. Need a strong system of communication, proactive enforcement and accountability.	CESAJ-SO CESAJ-CO	a. Require a full time contractor safety engineer with experience in mass concrete construction.	Safety/ Contract Admin.
		CESAJ-SO	b. Regular site visits from the Antilles Office safety officer, with quarterly visits from the district's safety officer.	Ditto.
		CESAJ-CO	c. The Resident Engineer shall attend monthly meetings with the contractor's project management staff in which safety is a regular agenda item.	Ditto.
		CESAJ-CO	d. Require construction representatives to attend contractor's weekly safety meetings.	Ditto.
		CESAJ-CO	e. Contractor's Accident Prevention Plan (APP) will include a effective systemic reporting, enforcement, and follow-up system that includes accidents, counter-measures, and the complete reporting of near-misses to all project personnel. The district will stipulate the requirements in the contract plans and specifications.	Ditto.
		CESAJ-CO	f. Documentation to include actions identified by inspections, Activity Hazard Analysis (AHA's), and monthly safety meetings will be coordinated through the: Superintendent and Resident Engineer; Foremen and CE inspector; and the contractor's and CE professional.	Safety/ Contract Admin

Final Review:

Jim Woodey
Chief, Safety Office

for Alex Merrison
Chief, Construction Branch

Charlie Osborne
Programs & Project Management

LTC Canton
Deputy Commander for Antilles Office

CERRILLOS DAM LESSONS LEARNED
E. ORGANIZATION

LESSONS LEARNED ACTION GROUP
6 DEC 1993

PROBLEM	LESSON LEARNED	ACTION OFFICE	PROCESS TO IMPLEMENT	DISCIPLINE
E-01 Disagreement existed in various stovepipes.	Partnering within the organization contributes greatly to a better product.	CESAJ-CO	a. Initiated efforts to better partner within district. Portugués Action Group (PAG) established. PAG through periodic meetings will address technical issues.	Design/ Contract Admin.
E-02 Slow resolution of problems.	Having periodic meetings at the district level will result in more efficient resolutions to problems.	CESAJ-CO	a. Same as above.	Design/ Contract Admin.
E-03 Numerous claims.	Claims that are not efficiently and fairly resolved can erode the relationships between the government and contractor.	CESAJ-CO	a. Improve communication with contractor through partnering. Resolve issues at lowest possible level. Use ADR technique if claims cannot be resolved.	Contract Admin./ Contracting Legal
E-04 Field personnel did not have a thorough understanding of Engineering Considerations and basis of design.	It is very important that the field personnel understand the intent of the designers.	CESAJ-EN-D	a. Schedule workshops between design engineers and field personnel prior to Portugués Dam construction. We have conducted one EN/CO workshop. Anticipate conducting additional workshops to continue this.	Design/ Contract Admin.

Final Review:

Jerry DiChiara
Chief, Construction-Operations Division

Nick Etheridge
Chief, Contracting Division

Edward E. Middleton, PhD., P.E.
Chief, Engineering Division

for Lloyd Pike
District Counsel

APPENDIX I
USACERL FACT SHEETS OF TWO KBES PROGRAMS

US Army Corps
of Engineers
Construction Engineering
Research Laboratories

P.O. Box 9005
Champaign, IL 61826-9005

Public Affairs and Marketing
Communications Office
Phone (217) 352-6511

Fact Sheet

June 1993 (FF 10)

KNOWLEDGE BASE FOR ALTERNATIVE CONSTRUCTION METHODS

The Problem

The U.S. Army Corps of Engineers (USACE) usually takes a single approach in its acquisition (design, procurement, and construction) of military facilities. However, other private and public construction markets are increasingly accepting and using other facility acquisition methods and innovative building technologies. Developments, such as new management systems, new materials, and new processes in construction, are increasingly being explored. The House of Representatives Committee on Appropriations recognized potential advantages in these alternative construction methods and asked that the Department of Defense use them more often where advantageous. The Corps does not have much experience using some of these different approaches. Therefore, a system is needed to provide guidance and track experiences using alternative construction methods on military projects and to transmit that knowledge to others who will use these methods in the future.

The Technology

The U.S. Army Construction Engineering Research Laboratories (USACERL) has developed a Knowledge Based Expert System (KEBS) to assist Corps management and technical personnel in using the Design/Build method of construction contracting. KEBS is an intelligent computer program that uses knowledge and inference to solve problems. Developing a way for the program to process, identify, and represent knowledge is essential for making KEBS a useful advisory tool.

The Design/Build Advisor KEBS uses an object-oriented representation scheme, which means that the steps in its "thinking" process and the decisions it makes are represented as objects. Elements of project-independent and project-dependent knowledge are represented as attributes of each process step. Relationships and heuristics are represented by rulesets. Capturing, organizing, and synthesizing process knowledge and providing it to a project planner or manager for any activity, at any time, is the primary goal of the Design/Build Advisor.

The Design/Build Advisor provides advice in three levels of detail. The first level is a graphic "road map" of the Design/Build process that describes the activities and decisions encountered throughout a Design/Build project. The second level contains general advice about conducting each activity. This advice would apply to any Design/Build project and

would contain guidance similar to that found in a text guidance document. Examples would include general information on selecting a project for a Design/Build approach, preparing specification documents, or evaluating the technical merits of a Design/Build proposal. While this advice is useful, it often does not address all the specific conditions of each individual project. For example, specification content, proposal content, and the criteria on which a contractor will be selected may differ from project to project. The third level of advice provides project-specific guidance. In response to queries from the system, the user provides information representing specific project conditions, such as local Design/Build practices, the applicability of commercial engineering standards, and mission-critical project features. Advice is then provided that reflects the specific project conditions.

The overall structure of the Design/Build Advisor will allow for updating and upgrading of knowledge as greater expertise is developed. It will also allow for the inclusion of additional types of alternative construction methods.

Benefits/Savings

KEBS will support decision-making and management of military projects using alternative construction methods by making advice and lessons-learned available from those who have conducted similar projects. Personnel with little first-hand experience in a particular alternative construction method will benefit from the expertise gained through others' experiences. As a result, a project will have a greater chance for success, even though those managing it may have limited experience. Furthermore, the system generates a comprehensive record of a project's progress and results, allowing for a more accurate assessment of an alternative construction method's effectiveness, and enabling the upgrading of advice and guidance.

Status

Military Construction, Army (MCA) and other selected military construction projects currently using Design/Build construction are being monitored. USACE has had positive experience with the MCA projects. Two Physical Fitness Centers were designed and constructed for approximately 29 percent and 16 percent less than estimated for conventional procedures. The design and construction of a commissary was accomplished in approximately half the time that it would have taken using conventional procedures. Design/Build procedures enabled an Unaccompanied Officers' Quarters to be built when using conventional procedures might have jeopardized the project.

USACERL Technical Report P-90/05, *Concept Knowledge Base for Alternative Construction Methods*, was published in FY90. A prototype Design/Build Advisor was completed in FY92. The prototype system is being upgraded in preparation for fielding by Headquarters, USACE.

Point of Contact

USACERL POC is Mr. Thomas R. Napier, COMM 217-373-7263; toll-free 800-USA-CERL (outside Illinois), 800-252-7122 (within Illinois); or USACERL, ATTN: CECER-FFC, P.O. Box 9005, Champaign, IL 61826-9005.

US Army Corps
of Engineers
Construction Engineering
Research Laboratories

Fact Sheet

P.O. Box 9005
Champaign, IL 61826-9005

Public Affairs and Marketing
Communications Office
Phone (217) 352-6511

October 1993 (FF 31)

CLAIMS GUIDANCE SYSTEM (CGS)

The Problem

Experienced project engineers are familiar with the general concepts that govern various types of legal situations as well as the definition of the language necessary to communicate with the District Office legal counsel. An inexperienced project engineer, however, faces numerous problems: what information is required when dealing with a potential claim, what information should be documented, and what type of contract documents should be reviewed prior to discussions with legal counsel? A new project engineer lacks the understanding of the legal issues involved in potential claims. With a readily available source for this information, lengthy claims and litigations caused by incorrect decisions and/or actions can be avoided.

The Technology

The U.S. Army Construction Engineering Research Laboratories (USACERL) is developing the Claims Guidance System (CGS), an expert system to provide Corps construction project engineers a training tool and assistance in making decisions on potential claims. This project uses the expert system approach of Artificial Intelligence. An expert system is a computer software that contains intuitive and judgmental knowledge of a human expert in some specific application. The four modules of CGS deal with the Differing Site Conditions, Changes, Default, and Suspension of Work Clauses.

To use CGS, the project engineer provides relevant information regarding a particular claim that he wishes to evaluate; CGS analyzes this information and provides recommendations based on the legal precedence. By using this system, the new project engineer will develop a sense of what information should be documented and reviewed in order to consult with legal counsel. CGS also produces a report that documents all relevant information.

Benefits/Savings

CGS will help Corps project engineers document necessary information and make appropriate decisions so that lengthy claims and litigations can be avoided, thus saving time

and money. It also may be used as a training device for inexperienced project engineers, assisting them in learning the legal issues related to different types of claims.

Status

The first and second modules were developed and reviewed by the CGS Steering Committee and field-tested at Fort Drum, NY, Fort Benjamin Harrison, IN, Baltimore District, and Louisville District. All four modules are currently being tested at the following offices: Southern California Area Office, Redstone Arsenal Area Office, Central Oklahoma Area Office, Omaha District, Fort Lewis Area Office, and North Eastern Area Office. Distribution of the system with a Cooperative Research and Development Agreement (CRDA) is also being considered.

Points of Contact

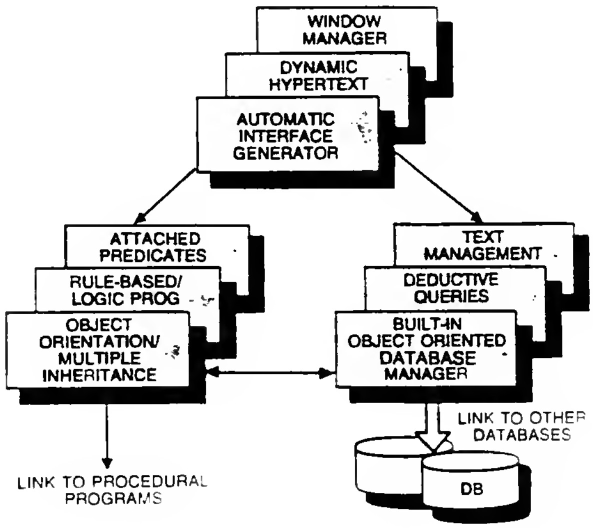
USACERL POCs are Don Hicks, COMM 217-373-6712, and Moonja P. Kim, COMM 217-373-7205. Both can be reached toll-free 800-USA-CERL (outside Illinois), 800-252-7122 (within Illinois); FAX 217-373-6724; or USACERL, ATTN: CECER-FFR, P.O. Box 9005, Champaign, IL 61826-9005.

APPENDIX J
VENDOR PRODUCT SHEETS FOR I/C AND KPWIN SOFTWARE

Intelligence Compiler™

The Challenge:

To produce quality software fast. There are just not enough programmers to meet application needs. Existing languages and tools offer no hope. Low-level and time-intensive programming must be replaced with higher-level programming constructs, intelligent development environments, and portable software architectures.



The Solution:

Intelligence/Compiler (I/C) is the highest-level quick-turn-around development environment available today. It integrates multiple programming paradigms within an intelligent development and compilation environment. Applications are generated effortlessly with I/C's embedded object-oriented database, rule-based logic, and dynamic hypertext.

How it Works:

Building an I/C application involves three steps. First, you generate sophisticated interfaces with the *Automatic Dialog Generator*. With a few clicks you create impressive mouse and/or cursor-driven dialogs in a graphic multi-window environment. I/C dialogs are flexible, they call each other, or are fired by objects, rules, and hypertext.

Next, you use the *Intelligent Editor* to construct a knowledge-base. You specify complex processes with a few simple built-in functions. With dynamic hypertext you define links between items via keyword search or by firing rules and accessing elements in databases, objects, and frames.

Finally, following *incremental compilation*, you trace your application's behavior in the *Interactive Execution Environment*. Forward/backward chaining, inexact reasoning, and procedure calls are supported, all with uniform control. The tracing environment is extremely flexible, and provides dynamic views of trace patterns.

You can call external programs and read external database files. Your I/C application ports across platforms without modification.

Applications/Benefits:

With I/C you accomplish in days what many programmers might struggle to accomplish in months. You'll generate dynamic dialogs. You'll create object-oriented networks of actions with attached predicates. You'll impress users with dynamic hypertext which is linked to rules and SQL.

I/C's comprehensive combination of multiple programming paradigms is not available in any other development environment. By combining object-oriented databases, intelligent dialogs, hypertext, rules, and SQL, I/C allows you to solve problems quickly by using a different programming paradigm for each application sub-task.

I/C has been successfully used in a multitude of application areas, ranging from inventory control and chemical engineering to financial analysis and field service planning. It has never been easier to build applications. Use I/C and develop quality software fast.

Product overview

KnowledgePro Windows, KPWin, is a fully object oriented, event driven programming language supplying a rich, powerful and flexible development environment for Windows applications.

Its intuitive natural feel and unique combination of expert system, list processing, hypertext functions, GUI design tools and multimedia facilities provide an essential integration of modern programming power and productivity.

KPWin shortens delivery cycles and improves the performance of experienced programmers with its OOP and list processing features and support for DDE and DLL. Its short learning curve allows professionals, experts and power users to build systems and exploit their own knowledge.

KPWin++ is the first complete high level language to generate efficient, reliable, error free, object oriented C++ code for the entire application.

KPWin is now the chosen tool of developers in a wide range of organisations, with delivery times being cut dramatically. An unparalleled ability to combine rule based systems with large amounts of data make it particularly suitable for rapid creation of multimedia applications, computer based learning and intelligent information systems.

With its broad appeal to mainstream application development KPWin has won numerous international awards since being named PC Magazine's Product of the Year.

KPWin SQLKIT is a fast and powerful tool providing KPWin and KPWin++ developers with easy access to many important database formats using SQL statements.

KPWin DBASE Kit lets you create and modify multi-user database files in dBASE III and IV format using dBASE or Clipper indexes.

The KPWin Maths Toolkit adds numerous mathematical functions to KPWin.

WRAP, the Windows Resource Archive Program, provides on-the-fly file compression and data management for text, image, sound and binary data. It is used for installation routines, security, application distribution and network data access.

The products are available as Bouquets in various combinations with training and support.

APPENDIX K
FDOT (DISTRICT 2) DEVELOPMENTAL INSPECTION CHECKLISTS

1 - PRODUCTION PILE INSTALLATION GUIDELINE

1-1 OFFICE PREPARATION

1.1 Review The Following Documents:
- (a) Standard and supplemental spec. A455, special and technical special provisions.
- (b) Plans, plans notes and soil borings.
- (c) Pile Driving Inspection Manual, Structures Foundation Construction Manual, and Construction Project Administration Manual (CPAM).
- (d) Contractor's Pile Installation Plan (PIP).
- (e) Geotechnical Engr's. Pile Driving Criteria (PDC).
- (f) Computation book.

1.2 Prepare Pile Driving Records Book and Field Driving Log.
1.3 Notify affected utilities and permitting agencies before driving begins.
1.4 Discuss special pile driving operations with Proj. Engr.
1.5 Review the status and location of overhead and underground utilities and underground obstructions.
1.6 Review the Accident Prevention Procedures Manual sections that cover safe practice during pile driving operations.

1-2 FIELD PREPARATION

2.1 Verify pile locations and survey staking.
2.2 Verify FDOT pile approval stamp on pile end: also age, strength and any deficiencies.
2.3 Check pick-up point patches for soundness.
2.4 Accurate foot marks on piles.
2.5 Contractor's equipment as per PIP.
2.6 Establish reference elev. for pile cut off.
2.7 Footing excavation per spec. 125-4.
2.8 Protection of existing structures per spec. A455-3.1.
2.9 Template per PIP and within 5' of CUT OFF
2.10 Prior to the first pile driving operation, a meeting should be held with the contractor to discuss governing specifications and contingency plans during the operation. Minutes of this meeting should be taken and distributed to contractor and CEI personnel.

1-3 PREFORMING PILE HOLES (A455-3.2.3)

3.1 Hole size greater than or equal to max. pile size except in rock, than 2" or greater.
3.2 Drill or punch must be guided by template or other device.
3.3 Hole depth shall not exceed pile penetration requirements.
3.4 Void between pile and hole must be filled with approved sand.
3.5 Grouted piles require min. void diameter between pile and hole of 2" greater than max. pile dimension.

1-4 PILE PLACEMENT

4.1 Check for proper no. of lifting points (see Prestressed Concrete Pile sheets in plans).
4.2 Jetting requirements (A455-3.8).
  (a) No jetting in completed embankments.
  (b) Jetting and driving with external jets requires 2 jets.
  (c) Jet nozzle should be approx. 3' above pile tip or as per engr.
  (d) All piles in a group shall be jetted prior to driving: when impractical, set checks are required.
  (e) Pumps, supply lines and jet pipes per PIP: min. pump capacity-250 gpm @ 50 psi, jet pipe min. 2" ID, feedlines min. 3" ID.
4.3 End Bent Pile Placement (A455-3.2.2 & 3.2.3).
  (a) Compacted fill shall be placed prior to driving piles except for reinforced earth walls or variations.
  (b) Preformed holes through embankment down to original ground elev. or an optional 4' below original ground, must be provided prior to pile driving: drill dia. spec. 455-3.2.3.
  (c) Preformed hole location and alignment tolerances shall be the same as for piles.
  (d) For caving soils, hole must be cased from original ground to grade and casing shall be filled with approved sand and removed.
  (e) When piles are placed prior to fill (RE walls, VSL walls, etc.) equipment weighing over 1000 lbs. must not be within a 15' radius of a pile and pile alignment shall be checked at 3 equal intervals during fill placement.

1-5 PILE DRIVING

5.1 Wear all personal safety equipment.
5.2 Choose optimum location to count hammer blows.
5.3 Fuel or slide bar settings must comply with PDC.
5.4 Verify that Contractor is checking and maintaining proper alignment of leads and pile (A455-3.17.3).
5.5 Fill out Pile Driving log keeping special driving procedures and precautions in mind.
5.6 For open end diesel hammers, the contractor is to provide a saxometer (A455-3.3.2).
5.7 Set Check Procedures (A455-3.11.4)
  (a) Review set check procedures in PDC.
  (b) Set check may be used when pile is within 1' of cut off and required resistance not reached.
  (c) At least 15 minutes must pass between stopping of production driving and the start of set check driving.
  (d) Very accurate penetration measurements must be taken by Contractor: blows counted at 1/8", 1/4", 1/2", 1", 2" and 3".
  (e) Original pile cushion should be used or a precompressed cushion.
  (f) Diesel hammers must be warmed up prior to set check driving: min. 20 blows.

5.8 Bearing and Penetration must be determined by meeting any of the following (A455-3.9):
- (a) Pile tip at or below min. penetration and 2 consecutive feet of blow count required by PDC obtained.
- (b) Min. penetration obtained and practical refusal reached (20 bpi for 2" or 30 to 40 blows in less than 2").
- (c) Min. penetration obtained and set check criteria met per PDC.

1-6 PILE SPLICES AND BUILDUPS: Review splice details in plans and standards

6.1 CONCRETE PILES (A455-5.12)
- (a) No greater than 5' below cut off, non-driven.
  - (i) Non-PS, precast reinforced, with same concrete mix, cross section and form material as existing section.
  - (ii) If 2' or less below cut off, same as (i) except CIP.
- (b) Greater than or equal to 5' below cut off, driven or non-driven.
  - (i) Splice must be PS & PC, min. 10' long if driven.
  - (ii) Pile cut off with original head may be used for splice.
- (c) Splice Inspection
  - (i) Damage to existing pile head must be cut off.
  - (ii) Dowel holes drilled with approved steel template, 2" deeper than dowel length.
  - (iii) Dowel holes must be cleaned by high pressure air jet and splice faces must be completely clean; holes and faces must be completely dry.
  - (iv) Epoxy adhesive mixed in accordance with manufacturer's specs.(see epoxy spec. 926): no sand or other filler material unless manufacturer includes in mix.
  - (v) If a pile cut off is used for a splice, the epoxy must be fully cured per manufacturer's specs. prior to attachment to existing pile.
  - (vi) Forms around splice joint should not leak and alignment of two sections must be precisely maintained until joint cures.
  - (vii) A spliced pile must not be driven until epoxy has cured for 48 hrs. or per manufacturer's specs. whichever is longer.

6.2 STEEL PILES (A455-6.3).
- (a) Splice material must meet spec. 962-2.
- (b) No splices permitted if driven length 40' or less.
- (c) Welded splices by certified welder and per spec. 460-6.
- (d) Splice Inspection
  - (i) Dress pile top with grinder so that edges are beveled for welding.
  - (ii) If used, tack weld backing plate with 1" overlap.
  - (iii) Joined sections receive full butt welds.

1-7 INSPECTION WRAP-UP

7.1 Verify final pile top elev. and alignment are within tolerance.
7.2 Verify that strands and reinforcement are severed prior to breaking of piles that require cut off.
7.3 Visually check pile for deficiencies.

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2 - GENERAL CONCRETE GUIDELINE

Footings, Columns, Caps, Beams, Walls
Traffic Barriers, Flat Slabs

2-1 PREPARATION

1.1 Review the following documents
- (a) standard & supplemental specs., special & tech. special provisions.
- (b) Plans and plan notes.
- (c) Level II quality control plan.
- (d) Mass concrete quality control plan.
- (e) Concrete design mixes.
- (f) Computation book.
- (g) Tricks of the Trade.
- (h) Job guide schedule.
- (i) The following publications covering concrete sampling procedures should be reviewed: ACT Certification Manual, pages 15, 21, 28, 35, 47, 53 and 63; FDOT Field Sampling and Testing Manual, sections FM 1-T023, T119, T121, T141, T152, T196, and 5-501.

1.2 Prepare the following records:
- (a) Materials sample log book (concrete, rebar).
- (b) Daily quantities sheet.

1.3 Prior to first concrete placements, a meeting should be held with the Contractor to discuss governing specifications and contingency plans during the operation. Minutes of this meeting should be taken and distributed to Contractor and CEI personnel.

1.4 Safety: Review the FDOT Accident Prevention Procedures Manual (1990) for all proper construction safety procedures. If an overhanging work platform is being used, check for its compliance with all OSHA and FDOT safety regulations.

2-2 PILE FOOTING PREPARATION

2.1 If bottom of excavation is too wet, excess water must be removed using any of these methods: well points, perforated sock or a rim ditch with or without pumping.

2.2 Natural soil bed must be firm enough to support plastic concrete. If not, soil must be replaced with suitable material.

2.3 Density of soil bed must be as per Supplemental Spec. 455-3.2.1.

2-3 FORMING

3.1 Forms must be dressed wood or metal of uniform thickness (400-5.1).

3.2 Verify correct line, grade, plumbness, levelness, mortar tightness and dimensions of forms (400-5.1).

3.3 Forms must be braced so that the vibrated concrete will not cause bulging between supports or an alignment shift. This is particularly critical for columns and walls (400-5.1).

3.4 Verify that friction collars for cap support are properly secured.

3.5 For type, quality and dimensions required for wood forms see spec. 400-5.3.

3.6 All concrete corners must have 3/4" x 3/4" chamfer unless otherwise shown, in plan (400-5.4.1).
3.7 All form surfaces in contact with concrete shall be treated with an approved form release product and be free of dirt or any other debris (400-5.6).
3.8 All inspection and cleanout holes shall be closed and secured (400-5.6).
3.9 Traffic Barriers: Ensure that top of form elevations are adjusted to account for high and low spots in the deck. Sight along top chamfer line with eye or with mirror to ensure a uniform top of barrier alignment.
3.10 Traffic Barriers: Check for proper horizontal alignment of wall relative to survey offset every 10' using a level or plumb bob by measuring to the back of the barrier wall.
3.11 Slip Forming Traffic Barriers
- (a) Check guide string for proper line and grade.
- (b) Verify that machine's vibrator is working properly.
- (c) Contractor must clean deck surface in path of slip forming machine.
- (d) Contractor's worker and the inspector should walk ahead of slip forming machine during placement to ensure that rebar cover adjustments are made before the slip former passes.

3.12 For flat slabs, the project engineer should review the contractor's falsework plans and calculations prior to any concrete placements.

2-4 PLACING AND TYING REBAR

4.1 Reinforcing steel shall be stored above the ground surface and shall be free of loose rust, scale, dirt, paint, oil and other foreign matter (415-3).
4.2 Hot bending, welding or flame cutting will not be allowed unless otherwise specified (415-4).
4.3 Placing and Tying
- (a) Each bar shall be tied within 1" of plan position unless otherwise specified (415-5.1).
- (b) Splices shall be securely clamped or tied. Minimum lap is 24 bar diameters unless otherwise specified (415-5.4).
- (c) Mortar blocks shall be composed of one part cement to two parts concrete sand and shall have wires cast into them for fastening to the steel. The blocks shall be moist cured at least three days (415-5.2).
- (d) Reinforcing steel must be secured so as not to move or rack (415-5.3).

4.4 Footings
- (a) Mortar blocks, if used, shall have dimensions not greater than 4" x 4" x plan clearance. Footing mat steel shall be placed within 1/2" vertically from the plan bottom clearance and within 1" from the plan side clearance (415-5.5.1 & 415.5.5.2).
- (b) Footing mat steel shall have double strand single tie at all perimeter intersections, and at alternating interior intersections (415-5.5.3).

4.5 Columns
- (a) Column dowel bars shall be placed within 1/2" of plan position, except that side clearance tolerance shall not exceed 1/4" from plan. Dowel bars shall not be set prior to concrete placement. Verify lap length for conformance with the plans (415-5.6.1,5.6.2)

(b) Column vertical bars shall be placed within 1/2" of plan position. Side form clearance shall be within 1/4" of that specified. Column steel shall be spaced off from that side forms by mortar blocks with dimensions not greater that 2" x 2" x plan clearance (415-5.7.1 & 415-5.7.29).
(c) Each column hoop shall be placed within 1" of its plan position. Side form clearance shall be within 1/2" of that specified (415-5.7.26).
(d) Column hoops shall be tied to the verticals at every intersection by a cross or figure 8 tie (415-5.7.3).

4.6 Wall Steel
(a) Wall steel shall be spaced off from the side forms by mortar blocks of dimensions not greater that 2" x 2" x plan clearance. Spacing between the mats shall be maintained by means satisfactory to the Engineer (415-5.8.1).
(b) Wall steel shall be tied with a cross or figure 8 tie at all perimeter intersections and at every third interior intersection at a minimum (415-5.8.3).

4.7 Beams and Caps
(a) Bottom clearance shall be maintained by approved heavy beam bolsters. Additional layers of main longitudinal steel shall be supported from the lower layers by heavy beam bolsters placed directly over the lower supports (415-5.9.1).
(b) The spacing of beam bolsters shall begin at not more than two feet from the end of the beam or cap and additional bolsters shall be spaced at not more that 4' (415-5.9.1).
(c) Mortar blocks having dimensions not greater than 2" x 2" x plan clearance and fastened to the steel by cast-in- wires, shall be used for spacing the upper main longitudinal steel below the top bars (415-5.9.1).
(d) The side clearance shall be maintained by mortar blocks of dimensions not greater that 2" x 2" x plan clearance and fastened to the steel by cast-in-wires (415-5.9.1).
(e) Main longitudinal steel shall be placed such as to provide a bottom and top clearance within 1/4" of the plan vertical dimensions for all layers. Spacing from side forms shall be within 1/2" of the specified spacing (415-5.9.2).
(f) Each stirrup shall be spaced and tied within 1" of its plan position (415-5.9.2).
(g) Tying shall be double strand single ties at all intersections (415-5.9.3).

4.8 Traffic Barriers
(a) Rebar should be free of hardened concrete and curing compound deposited during the deck pour.
(b) Tie wires must not extend into the concrete cover layer.
(c) Check for excessive longitudinal misalignment of rebar prior to placing the forms.
(d) Deck surface below barrier rebars must be cleaned of all foreign and loose matter and must be at proper grade to ensure full cover of top rebar.
(e) Utility conduits and embedments must be separated from rebar to allow concrete to flow between and around them.
(f) Verify that utility conduit slip joints and junction boxes are properly installed.

2-5 PLACING CONCRETE

5.1 Temperature Restrictions (400-7.1)
- (a) Concrete shall not be placed if the outside air temperature is 35 degrees F and falling or if the concrete temperature is below 45 degrees F or above 90 degrees F (100 degrees F if a hot weather mix is approved).
- (b) Once concrete is placed, if the air temperature falls below 35 degrees F for 12 or more hours, the air and concrete must be heated to 60 degrees F.
- (c) If concrete temperature is above 75 degrees F, retarder must be used.
- (d) When the plans call for mass concrete, special temperature monitoring must be performed by the Contractor which should be verified by the Inspector (Supplemental Spec. 346-3.3).

5.2 Night placement requires an approved lighting system (400-7.2).

5.3 Concrete shall not be placed until foundations, forms, falsework and rebars have been inspected and approved (400-7.3).

5.4 Placement (400-7.5)
- (a) Concrete shall be placed, as near as possible, in its final position and in level layers. Concrete should not be placed in mounds and then leveled or moved with a vibrator.
- (b) Concrete should flow under and around rebars without displacing them.
- (c) Aggregates must not be segregated or separated.
- (d) Concrete can be dropped a maximum of 5' if not contained by a chute, tremie pipe or trough.
- (e) Troughs and chutes must be metal or metal lined and if steeply sloped, baffles or reversals are required. Troughs, chutes and pipes longer then 30' must be authorized. All of these must be free of coatings of hardened materials.
- (f) Contractor operations such as pile driving or other sources, such as motor vehicle traffic, must not produce vibrations that are detrimental to proper concrete curing.
- (g) A backup concrete placement system must be immediately available in case pumps, conveyors, cranes, etc. fail.

5.5 Belt conveyors must be authorized, not exceed 550' in length and discharge into a hopper at belt end (400-7.6).

5.6 If concrete is pumped, the discharge pipe must have a minimum pipe diameter of 4", concrete must not be in contact with aluminum and test samples must be taken at the discharge end (400-7.7).

5.7 Layers (400-7.10)
- (a) Layers of concrete should be horizontal, approximately 12" thick and placed within 20 minutes. The layer immediately below the layer being placed must not have an initial set and should have a rough surface.
- (b) Joints between layers can be avoided if the vibrator penetrates through the top layer and well into the underlaying layer.
- (c) Feather edges must not be produced at joints between layers.

5.8 Vibration (400-7.11)
- (a) All concrete placements must receive mechanical vibration with exceptions covered in the specifications.
- (b) Number of, type and size of vibrators must be approved and must have a minimum of 4500 IPM. A spare vibrator must be available.

(c) Vibrators shall not be used to move concrete but shall be inserted and withdrawn as near to plumb as possible in a slow and steady manner. Circles of vibrator influence shall overlap to ensure that the entire placement is adequately vibrated.
(d) Placements that can not be vibrated, shall be rodded or spaded by hand.

5.9 Columns (400-7.12)
(a) Column concrete shall be placed in one continuous operation unless construction joints are shown in the plans.
(b) Columns must cure at least 12 hours prior to cap form placement.

5.10 Slabs (400-7.13.1)
(a) Screeding system must be approved prior to placement.
(b) Concrete must be placed in continuous strips (transverse or longitudinal) with no time for initial set between strips except at planned joints.

5.11 Weather Protection (400-7.13.5)
(a) Unhardened concrete must be completely protected from rain and runoff by a system that does not come in contact with the concrete.
(b) A rain protection system must be demonstrated prior to placement and must be located close enough to placement site to be immediately available if rain is forecast.
(c) Concrete placement shall not begin if rain is likely to fall during operation.

2-6 CURING

6.1 No further curing is required if forms are kept in place, without loosening, for a least 3 days. (400-16.1)

6.2 Acceptable curing methods include continuous-moisture curing, steam curing, membrane curing compound or an impervious covering. (400-16.1.2)

6.3 Membrane Curing Compound (400-16.1.2)
(a) Mechanical mixing must take place just prior to each application of compound.
(b) Application shall be according to manufacturer's recommendations, at a rate of a least 200 sf per gallon and be sprayed as a uniform mist.
(c) Application by spraying shall be by compressor driven equipment and standby equipment shall be available.
(d) Hand held pump-up sprayers are not permitted except for standby use or on Class I concrete (non-pavement).
(e) Curing compound must be a type that does not reduce the bond between the concrete and class V applied finish.

6.4 Covers for continuous-moisture curing shall be kept continuously wet for at least 72 hours (400-16.1.2).

6.5 Construction Joints (400-16.3)
(a) Curing methods shall include leaving forms in place or continuous-moisture.
(b) Continuous-moisture may be applied by at least three layers of burlap or equal kept wet, covering with 1/2" layer of wet sand or sawdust or complete sealing with an impervious plastic cover.
(c) Where projecting rebars conflict with covers, membrane curing compound may be used.

6.6 If forms are left in place for traffic barriers, an approved curing method must be used for the exposed top surface.

2-7 FORM REMOVAL

7.1 Time of removal of forms shall be per plans, determined from compressive strength tests as per table in Special Provisions article 400 forms-removal, or as directed.
7.2 Compressive strength to be determined from cylinders cast from same conditions as concrete in corresponding bridge component (400-14).
7.3 Casting, curing and testing of cylinders shall be performed by Contractor at his expense, in accordance with AASHTO T22 and T23 and under observation of the Department (400-14).
7.4 Forms may be removed when compressive strength is equal or greater than percentage of specified design strength as shown in the table in Special Provisions article 400 forms-removal.
7.5 Concrete in cofferdams must not be exposed to the action of water prior to final set and must not be exposed to salt or brackish water for 7 days after placement. Protection of concrete must be accomplished by pumping salt or brackish water out of cofferdams (400-7.4).

2-8 FINAL FINISHING

8.1 Remove form tie ends. Remove irregular projections. Patch void, honeycomb and form tie holes (400-15).
8.2 Mortar for patching shall comply with spec. 400-15.1 and generally be 3 parts concrete sand to 1 part portland cement. Surface to be patched shall be roughened and free of all foreign matter.
8.3 If a Class I-IV surface finish is required, refer to spec. 400-15.2.2 through 400-15.2.5.
8.4 Class V Coating (textured paint) (400-15.2.6)
- (a) Must arrive in manufacturer's container bearing the manufacturer's original labels. A copy of the manufacturer's instructions shall be made available to the engineer.
- (b) Surfaces must be prepared in accordance with manufacturer's specs.
- (c) Must be applied in accordance with manufacturer's specs. Application rate of 40-50 SF/GAL.
- (d) Finished surface must have a uniform texture and color, and not exceed 1/8" thickness.
- (e) For material test and certification procedure, see spec. 400-15.2.6.7.

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4 - BRIDGE DECK GUIDELINE

4-1 PREPARATION

1.1 Review the following documents:
  (a) Std. and supp. specs., special and technical special provisions.
  (b) Plans, plan notes and shop drawings.
  (c) Level II quality control plan.
  (d) Concrete mix designs.
  (e) Computation book.
  (f) Tricks of the trade manual.
  (g) Job guide schedule.
  (h) Proper concrete sampling procedures: ACI Certification Manual, pages 15, 21, 28, 35, 47, 53 and 63; FDOT Field Sampling and Testing Manual, sections FM 1-T023, T119, T121, T141, T152, T196 and 5-501.

1.2 Prepare the following records:
  (a) Daily quantities sheets.
  (b) Materials sample log book (concrete and rebar).
  (c) Deck thickness, clearance and straight edging verification log.
  (d) Prepare a pour map that will identify where each concrete truck's load is located in the deck.

1.3 Prior to the first deck placement, a meeting should be held with the Contractor to discuss governing specifications and contingency plans during the operation. Minutes of this meeting should be distributed to Contractor and CEI personnel.

1.4 Safety: Review the FDOT Accident Prevention Procedures Manual(1990) for the proper construction safety practices. Do not walk beams without a safety belt attached to a safety line.

4-2 FORMING

2.1 Removable forms
  (a) Forms must be dressed wood or metal of uniform thickness (400-5.1).
  (b) Verify correct line, grade, plumbness, levelness, mortar tightness and dimensions of forms (400-5.1).
  (c) Forms must be braced so that the vibrated concrete will not cause bulging between supports or an alignment shift. (400-5.1).
  (d) For type, quality and dimensions required for wood forms see spec. 400-5.3.
  (e) All concrete corners must have 3/4" x 3/4" chamfer unless otherwise shown in plans (400-5.4.1).
  (f) Verify with Engineer that forms and/or falsework are adequate for supporting the load.

2.2 Stay in Place (SIP) Metal Forms (400-5.7.1 thru 5.7.6)
  (a) Prior to erection of SIP forms, the following must be approved by the FDOT: materials, forming system, fabrication, erection method and shop drawings.
  (b) Rebar cover must be minimum shown in plans.
  (c) Form flutes do not count as cover.
  (d) SIP forms are not permitted in bays with longitudinal deck joints.
  (e) Forms shall not be welded to beams or support angles but instead shall be securely fastened by bolts, clips, etc.

(f) The welding process for connecting the support angle to the flange strap must not come in contact with beam flange steel.
(g) Flange straps must be in direct contact with the beam flange.
(h) Form panel ends must overlap support angles by at least 1".
(i) Damaged galvanizing must be touched up per specifications.
(J) Transverse deck joints should be over flute bottoms and the bottoms shall have 1/4" dia. weep holes on 12" centers.
(k) It is desirable to verify form locations with a stringline prior to rebar placement.
(l) After concrete has hardened, SIP forms should be tapped (sounded) with a mallet to check for proper bond and for the existence of voids.

4-3 PLACING AND TYING REBAR (415-5.10 & 13)

3.1 Reinforcing steel shall be stored above the ground surface and shall be free of loose rust, scale, dirt, paint, oil and other foreign matter (415-3).
3.2 Hot bending, welding or flame cutting will not be allowed unless otherwise specified (415-4).
3.3 Each bar shall be tied within 1" of plan position unless otherwise specified (415-5.1).
3.4 Splices shall be securely clamped or tied. Minimum lap is 24 bar diameters unless otherwise specified (415-5.4).
3.5 Mortar blocks shall be composed of one part cement to two parts concrete sand and shall have wires cast into them for fastening to the steel. The blocks shall be moist cured at least three days (415-5.2).
3.6 Bottom rebar mat support: When bolsters are used, at least 2 rows must be placed between beams and the spacing between rows must not exceed 4'. One bolster row shall be placed 6" from the coping. With approval of the Engineer, mortar blocks may be used in lieu of bolsters and must be spaced on 4' centers maximum. Blocks must be 2" x 2" x concrete cover.
3.7 Top rebar mat support: 2 rows of continuous high chairs shall be used between beams and shall be spaced 6" from beam flange edges and one continuous row shall be 6" from the coping. If individual high chairs are used they shall be spaced as are continuous ones but longitudinal spacings shall not exceed 48". For prestressed beams, shear connector rebars may be used for top mat support with one row of high chairs between beams.
3.8 Rebar placement tolerance is 1/4" for all clearance.
3.9 Tying for each mat: a double strand single tie must be used at every intersection on the periphery and for all other intersections at every third location.
3.10 Metal rebar supports: Metal rebar supports in contact with SIP forms or that bear on removable forms must be protected from corrosion by a plastic coating at least 1/2" from the form or by solid plastic legs. Materials for rebar supports shall be in compliance with specification 415-5.13.

4-4 SCREED DRY RUN (Recommended procedure for checking deck thickness and rebar clearance)

4.1 Should be performed after rebars have been placed and screed rails and headers are set.
4.2 Thicknesses and clearances should be checked in every bay at longitudinal intervals not greater than 10'.
4.3 Check with Project Engineer for deck thickness variances due to: curved girders, multiple beam depths and/or lengths within one span, or for variations in beam loading, particularly for steel beam spans.
4.4 Deck thickness and rebar clearance measurements should be taken from the bottom of the screed rollers.
4.5 The screed rollers should be directly over the point where the measurement is to be taken.

4-5 PLACING DECK CONCRETE (400-7.13 & 7.1.2)

5.1 Approvals: screed or strike off device.
5.2 Concrete placed in continuous strips (transverse or longitudinal with no time for initial set between strips except at planned joints. Continuous beam decks must be placed according to pouring sequence in the plans. Concrete placement rate 16CY/hour or greater. (7.13.2)
5.3 Temporary erection supports must be removed for steel beams before deck placement. (7.13.3)
5.4 Intermediate diaphragms must be poured at least 48 hours before deck. (7.13.4)
5.5 Unhardened concrete must be completely protected from rain and runoff by a system that does not make contact with the concrete. (7.13.5)
5.6 Rain protection system must be demonstrated prior to pour and must be immediately available if rain is forecast. (7.13.5)
5.7 Forms and rebar shall be sprayed with cool fresh water just prior to deck placement of concrete in hot weather. (400-7.1.2)

4-6 SCREEDING AND FINISHING (400-7.15) & (400-15.2.5 & 9.7)

6.1 Prior to all concrete placement all bulkheads and rails must be set to proper grade - screed must adjust for all variances (vertical curve, camber, grade breaks, etc.), intermediate rails not permitted. (7.15.1)
6.2 Screed shall be mechanical, vibratory and must retain its shape and be approved prior to use. (7.15.2)
6.3 Screed passes shall be as many as required for an acceptable surface. (7.15.3)
6.4 After screeding and before finishing, deck must be longitudinally straight edged with 10' bar, half lapped, 5' transversely. If unevenness is more that 1/8" then deck surface shall be corrected immediately.
6.5 After water sheen and before initial set, the deck surface must be finished with burlap, fine broom, belt, or float. No grooves, marks, or scratches are allowed greater that 1/16" in depth.
6.6 Required saw joints must be installed the day after concrete placement (400-9.7).

4-7 DECK CURING (400-16.2 & 17.2)

7.1 Apply Type H (white) curing compound to deck surface immediately after finishing.
7.2 Saturated, properly sealed curing blankets must be placed as soon as possible without affecting surface texture for a minimum of 7 days - blanket materials must meet specifications.
7.3 Deck must be protected if lightly loaded during 7 days curing and loading must be authorized.
7.4 Temporarily uncovered surfaces during curing period must be sprayed with water during entire exposure.
7.5 Heavy loads must not be applied during 14 days after concrete placement and if applied, shall be only after the Department's approval.

4-8 FORM REMOVAL

8.1 Time of removal of forms shall be per plans, determined from compressive strength tests as per table in Supplemental Specifications article 400 forms-removal, or as directed.
8.2 Compressive strength to be determined from cylinders cast from same conditions as concrete in corresponding bridge component (400-14).
8.3 Casting, curing and testing of cylinders shall be performed by Contractor at his expense, in accordance with AASHTO T22 and T23 and under observation of the Department (400-14).
8.4 Forms may be removed when compressive strength is equal or greater than percentage of specified design strength as shown in the table in Supplemental Specifications article 400 forms-removal.

4-9 GROOVING

9.1 Grooving shall take place only after the concrete has cured for 7 days, has reached minimum required strength and before opening to traffic.
9.2 Prior to grooving, straight edging as denoted in 4-6.4 (above), shall be done. Irregularities over 3/16" must be ground down by abrasive method to 1/8" unevenness or less.
9.3 Grooves sawcut to 1/8" - 3/16" wide and 1/8" - 1/4" deep with detailed spacing and tolerances per specifications. Grooves must be continuous from gutter to gutter and within 18" of gutter.
9.4 Grooves must be per specifications at joints and for skews.

APPENDIX L
PROPOSED PCC LESSONS LEARNED DATA ENTRY FORM

UF PCC-LL (Sheet 1)
No. 95 __ __

POST CONSTRUCTION CONFERENCE
LESSONS LEARNED

I. GENERAL CONFERENCE INFORMATION

Recorded by: ____________ ***Location:*** ____________ ***Date:*** ____________

II. CONFERENCE ATTENDEES

	Name	*Affiliation*	*Project Role*
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

III. GENERAL PROJECT INFORMATION

Project Title: ____________

____

Project Scope: ____________

____

____

Project Location: ____________

District: ____________

WPI Number: ____________

State Project Number: ____________

Contract Number: ____________

Contract Amount: ____________

Project Start Date: ____________

Current Percent Complete: ____________

Anticipated Finish Date: ____________

UF PCC-LL (Sheet 2)
No. 95 __ __

III. LESSON LEARNED

Problem Backround: ____________________

Problem Resolution: ____________________

Special Notes: ____________________

APPENDIX M
THE IN REACH PROTOTYPE SYSTEM KPWIN SOURCE CODE

```
(* load library *)

#include qelibb.tpx
#include unit11.kb related


(**********************************************************)
(*                        Main Program                     *)
(**********************************************************)
(*                        IN - REACH                       *)
(**********************************************************)

(* Set up of variables *)

 tInfo is system_info ().
 Col is first (?tInfo).
 Row is element (?tInfo, 2 ).
 First_time is true.
 dele is true.

(* Init dataBase Connection *)

 qe_init().
 hdbc = qeConnect ('DRV=QEDBF').
 if ?hdbc = 0
   then
   window () and
   text ('FILES HAVE BEEN CORRUPTED  !!!', #n, 'please EXIT, and start over') and
   button (EXIT, clear, 15, 6) and
   wait ().

 First_time2 is true.

(* open first screen - Main Menu *)

 wprese is window ( ,1,1,?col,?row,'IN
REACH',[thickframe,maximized,maximizebox,popup,titlebar,controlmenu],,,darkgray).
 prese = load_bitmap ('prese.bmp').
 Button2('     CONTINUE      ',foll,12.7,25.5).
 Button2(' INTRODUCTION  ',introd,37.2,25.5).
 Button2('        EXIT          ',EXITL,61.3,25.5).
 bitmap (?prese,1,1).
 show_window(?wprese,8).
 wait().

(* end Main Menu *)


(* Exit Procedure *)
TOPIC EXITL().
 RetCode = qeDisconnect (?hdbc).
 clear().
END.
```

```
(* Introduction procedure *)

TOPIC INTROD().
 intr is window (
,1,1,?col-0,?row-2.3,'INTRODUCTION',[thickframe,,popup,titlebar,controlmenu,vertscroll],,,lightgray).
 show_window(?intr).
 text_int is read('intro1.txt').
 text(?text_int).
 wait('  CONTINUE  ').
 close('intro1.txt').
 close_window(?intr).
 text_int is [].
END. (* end introduction procedure *)


(* General Categories Menu *)

TOPIC FOLL().
 text(#e).
 prese = load_bitmap ('prese1.bmp').
 Button2('         BRIDGES          ',MAIN,10,21).
 Button2('          ROADWAY          ',MESS,35.9,21).
 Button2('       ASPHALT       ',MESS,64.1,21).
 Button2('SIGNALING && LIGHTING',MESS,10,24).
 Button2('MAINTENANCE OF TRAFFIC',MESS,36,24).
 Button2('        OTHER        ',MESS,64.15,24).
 bitmap (?prese,1,1).
 wait().
END. (* end General Categories Menu *)

(* Options Under Development *)

TOPIC MESS().
  D IS WINDOW( ,9.9,20.2,73.9,6.4,'SORRY
!!',[child,siblings,showChildren,visible,thinframe,titlebar],?WPRESE,,LIGHTGRAY,,).
  TEXT('
   The "General Category" that you have chosen is still under development.

       Please wait a moment, and then select another "General Category".').
  WAIT(,6).
  CLOSE_WINDOW(?D).
  FOLL().
END.

(*******************************************************)
(* Main Program *)

TOPIC MAIN().

(* Set up variables *)

  set_error_topic (err).
  close_window(?wprese).
  GEN_P IS 1.
```

```
 Set_event_topic (exitl,close_event).
 illust is false.
 hyper_display(green2).
 back_for is [].
 whichfile is [].
 cfgfile is [].

(* open main screen *)

 wbatata is window ( ,1,1,?col,?row,'IN REACH (General Category -
BRIDGES)',[thickframe,maximized,maximizebox,popup,titlebar,controlmenu],,,darkgray).
 show_window(?wbatata,8).

(* load Buttons *)

 resetbmp = load_bitmap ('resetu.bmp').
 backbmp = load_bitmap ('backu.bmp').
 searchbmp = load_bitmap ('searchu.bmp').
 forbmp = load_bitmap ('foru.bmp').
 sorbmp = load_bitmap ('souru.bmp').
 clearbmp = load_bitmap ('clearu.bmp').
 exitbmp = load_bitmap ('exitu.bmp').
 clearibmp = load_bitmap ('cleariu.bmp').
 new (ii, GraphicButton, [?clearibmp, close_illust,8.3+7.3+7.3+7.3+7.3,1]).
 hide_window(?ii).
 new (b1, GraphicButton, [?resetbmp,reset,1, 1]).
 new (b2, GraphicButton, [?backbmp,back, 8.3, 1]).
 new (b3, GraphicButton, [?searchbmp, bsearch,8.3+7.3+7.3,1]).
 new (b5, GraphicButton, [?forbmp, forprod,8.3+7.3,1]).
 new (b6, GraphicButton, [?sorbmp, sorprod,8.3+7.3+7.3+7.3,1]).
 new (b7, GraphicButton, [?clearbmp, clearprod,8.3+7.3+7.3+7.3+7.3,1]).
 new (b4, GraphicButton, [?exitbmp, exitl,8.3+7.3+7.3+7.3+7.3+7.3,1]).

(* initialize main screen *)
 init().


(* open all windows *)

 w5 is window ( ,?col-30.2, ?row-27.75,30.5,10.7,'Navigational
History',[popup,showChildren,titlebar,thinframe,vertscroll],?wbatata,,lightgray).
 wbasep is window(,?col-30.2, ?row-27.75+10.7,30.5,9,'Search
By',[popup,showChildren,titlebar,thinframe,vertscroll],?wbatata,,lightgray).
 wbaser is window(,?col-30.2, ?row-27.75+10.7,30.5,9, 'Search
By',[popup,showChildren,titlebar,thinframe,vertscroll],?wbatata,,lightgray).
  hide_window(?wbaser).
 wbases is window(,?col-30.2, ?row-27.75+10.7+9,30.5,9,'Related
Topics',[popup,showChildren,titlebar,thinframe,vertscroll],?wbatata,,lightgray).
 show_window (?w5).
 show_window (?WBASEp).
 show_window (?WBASES).
 set_active_window(?wmain).
```

```
(* initialize main list *)

 ANTES is 'BRIDGES'.
 BRIDGES().

(* first screen of Bridges *)
TOPIC BRIDGES().
   set_display_window(?wmain).
    text(#e).
(* load bridge image *)

    PT = load_bitmap ('IMAGE7.bmp').
    bitmap (?PT,1,1).
  set_display_window(?wmain).

(* Write in screen bridge information *)

      TEXT('#x2#y20.7            Welcome to the General Category of BRIDGES
#y22  From this screen, you can either:
#y23.1    1. - Click on #mBRIDGES - SOURCE INDEX#m  to enter BRIDGES
         directly via a hypertexed index of sources, or
#y25.25    2. - Run the other search rountines by clicking the "Search By"
         button located within the button bar at the top of the screen.').
  set_display_window(?w5).
  text('#m#lBRIDGES#m#N').
END. (* end Bridges *)

(* initialize wrap library *)

topic wrap_load_text (RAPFILE, DESCRIPTION).
 wrap_load_text is user (?WRAPLib, wrap_load_text, [?RAPFILE, ?DESCRIPTION]).
 end.

topic WRAPLib.
    WRAPLib is load_library ('kpwrap.dll').
end.

topic err(number,command,parms).
if ?number is 'WRAP_CANT_LOAD' or 'I_V_TOPIC_NOT_FOUND'
 then
   D IS WINDOW( ,1.54,3.4,56.3,26.3,'SORRY
!!',[child,siblings,showChildren,visible,thinframe,titlebar],?WBATATA,,LIGHTGRAY,,) and
  TEXT('

      You have attempted to retrieve a topic name that does not

      exist.  Please wait a moment, and IN REACH will return you

      to the screen where you were previously at prior to your

      clicking on the "Search By" and "List of Topics" buttons.').
```

```
  WAIT(,11) and

  CLOSE_WINDOW(?D) and
 ERROR = 1.

end.

(* Main Buttons Procedures *)

(* Home Procedure *)
topic reset.
if ?illust is true then close_illust().
 BRIDGES().
end.

(* Clear History Procedure *)
topic clearprod().
 antes is ''.
 GEN_P IS 1.
 set_display_window(?w5).
 GEN_P IS 2.
 text(#e).
 text('#m#lBRIDGES #m#N').
end.

(* Source Procedure *)
topic sorprod().
 if ?illust is true then W15 IS WINDOW(,1.54,3.4,(?col-35.1), 5, , [child, siblings,thinframe, showChildren,
visible], ?w1,,,) else
 W15 IS WINDOW(,1.54,3.4,(?col-35.1), 5, , [child, siblings,thinframe, showChildren, visible], ?wbatata,,,).
 INFO IS ''.
  sor_ls is concat('SELECT SOURCE FROM SOURCESS.DBF WHERE TOP_DESCRP =
''',LAST(?ANTES),'''').
  hstmt = qeExecSQL(?HDBC,?SOR_LS).
  while  (qeFetchNext (?hstmt) = 0) then
 INFO = get_string (qeValChar (?hstmt, 1, , )).
 rc is qeendsql(?hstmt).
 SHOW_WINDOW(?W15).
SET_DISPLAY_POS(1.3,2).
 TEXT(?INFO).
 button ('OK',CONTINUE,45, 3.5).
  wait ().
close_WINDOW(?W15).
end.

(* Back Procedure *)
                                    topic back().
 if ?illust is true then close_illust().
  if list_length(?ANTES) = 1
    then BRIDGES()
    ELSE
      back_for gets(last(?antes)) and
```

```
        ANTES is sublist (?ANTES, 1, list_length (?ANTES) - 1) and
        item is last (?ANTES) AND
        ANTES is sublist (?ANTES, 1, list_length (?ANTES) - 1) and
        dele is false and
        MARK(?ITEM).
end.

(* forward Procedure *)

topic forprod().
if ?back_for <> [] then
  dele is false and
 mark(last(?back_for)) and
  back_for is different(?back_for,last(?back_for)).
end.



(* end BUTTONS Procedures *)

(* Hypertext Handler *)

topic mark (item).
if ?illust is true then close_illust().
if ?dele is true then  back_for is [] else dele is true.
  ANTES GETS?ITEM.

   if list_length(?ANTES) = 1
     then palabra is  'BRIDGES'
     ELSE
       ANTES is sublist (?ANTES, 1, list_length (?ANTES)) and
           item is last (?ANTES) AND
           ANTES is sublist (?ANTES, 1, list_length (?ANTES)) and
           palabra is ?item.

(* write in History Windows *)

  set_display_window(?w5).
  text('#m#l', ?palabra ,'#m   ').
  GEN_P IS ?GEN_P +1.
VERT_SCROLL_TEXT(?w5,1000).
  set_display_window(?wmain).
  text(#e).

(* Check for Ilustration *)

 x = string_where(?item, 'Illustration').
 pepe is ?item.
 if ?x > 0
  then figura(). (* load Illustration *)
if ?x = 0 then
```

```
 IF ?ITEM = 'BRIDGES'  THEN BRIDGES()
  ELSE

(* Load from wrap file *)

    input is wrap_load_text (dot457,?item) and
    set_text (?wmain,[#n,#n,?input ]).
 input is [].

(* Load Illustration *)
 topic figura(item).
  show_window(?ii).
   W1 IS WINDOW(,1,4.5,?col,?row-4,?pepe,[popup,showChildren,titlebar,thinframe,vertscroll],?wbatata,,,,).
   SHOW_WINDOW(?W1).
  if ?pepe is 'Illustration-Metal Bar Chairs' then gilda is  load_bitmap ('image1.bmp').
  if ?pepe is 'Illustration-Precst Pile Splice' then gilda is  load_bitmap ('image2.bmp').
  if ?pepe is 'Illustration-Screed Machine' then gilda is  load_bitmap ('image3.bmp').
  if ?pepe is 'Illustration-Bar Identification' then gilda is  load_bitmap ('image4.bmp').
  if ?pepe is 'Illustration-Table of Bar Size' then gilda is  load_bitmap ('image5.bmp').
  if ?pepe is 'Illustration-Pile Driving Form' then gilda is  load_bitmap ('image6.bmp').
   bitmap (?gilda,1,1,,).
   illust is true.
  disable_window(?b7).
  hide_window(?b7).
end.
end. (* end Mark*)

(* topic From Close Illustration Button *)

topic Close_illust().
   CLOSE_WINDOW(?W1).
   illust is false.
  hide_window(?ii).
  enable_window(?b7).
  show_window(?b7).
  back().
end.


(* Object definitions for Graphics Buttons *)

topic GraphicButton (bmpObject, event, col, row, type, tParent ).
  :gbEvent is ?event.
  :gbType is ?type.
  :gbBitmap is ?bmpObject.
  [:gbWidth, :gbHeight] is_c bitmap_info(?bmpObject).
  :gbSelected is False.
  tParent is get_display_window ().
(*/3*)
  :handle is window (mouse_select_object, ?col, ?row, (?gbWidth)+0.3, ?gbHeight+0.18,,
[child,siblings,showChildren,thinframe], ?tParent,,lightgray,[mouse_down_event,mouse_up_event]).
  parent (handle) is ?handle.
```

```
bitmap(?gbBitmap).
show_window (?handle).
set_display_window(?tParent).

topic mouse_select_object(i, event, h).
 do (?event).

 topic mouse_down_event.
  set_display_window(?handle).
  text(#e).
 bitmap(?gbBitmap).
  update_window(?handle).
  set_event_topic (mouse_off_object, [ mouse_up_event, mouse_drag_event]).
  gbSelected is True.

  topic mouse_off_object (i, event, h).
   if ?h is ?handle then (
    if ?gbSelected is False then
     set_display_window(?handle) and
     text(#e) and
     bitmap(?gbBitmap) and
     update_window(?handle) and
     gbSelected is True )
   else (
    if ?gbSelected is True then
     set_display_window(?handle) and
     text(#e) and
     bitmap(?gbBitmap) and
     update_window(?handle) and
     gbSelected is False ).
   if ?event is mouse_up_event then (
    if ?h is ?handle then
     mouse_off_object is False
    else
     Set_Event_Topic() and
     mouse_off_object is True )
   else
    mouse_off_object is True.
  end.
 end.
 topic mouse_up_event.
  if ?gbSelected is True then
   set_display_window(?handle) and
   text(#e) and
   bitmap(?gbBitmap) and
   update_window(?handle) and
   Set_Event_Topic() and
   gbSelected is False and
   do (?gbEvent, ?gbType).
 end.
end.
end.
```

```
(* Main Search Procedure *)

topic bsearch().
 if ?illust is true then close_illust().
  disable_window(?b1).
  disable_window(?b2).
  disable_window(?b3).
  disable_window(?b4).
  disable_window(?b5).
  disable_window(?b6).
  disable_window(?b7).
  set_active_window(?wbatata).
  set_display_window(?wbatata).
  set_active_window(?wbasep).
  set_display_window(?wbasep).
  show_window(?wbasep).
  set_title(?wbasep,'Search By').

 bmpser1 = load_bitmap ('topics.bmp').
 bmpser2 = load_bitmap ('topics1.bmp').
 bmpser3 = load_bitmap ('topics2.bmp').
 bmpser4 = load_bitmap ('cancelu.bmp').
 if ?first_time is 'true' then

(* Load Search Buttons *)

  new (base1, GraphicButton, [?bmpser1,search,1, 1]) and
  new (base2, GraphicButton, [?bmpser2,search2,9.8+8.8,1]) and
  new (base3, GraphicButton, [?bmpser3,search1,9.8, 1]) and
  new (base4, GraphicButton, [?bmpser4,search3,9.8+8.8, 6]) and
  first_time is false
  else
   show_window(?base1) and
   show_window(?base2) and
   show_window(?base3) and
   show_window(?base4).
  disable_window(?wmain).
  disable_window(?wbases).
  disable_window(?w5).

(* Cancel Procedure *)

topic search3().
hide_window(?base1).
hide_window(?base2).
hide_window(?base3).
hide_window(?base4).
enable_window(?wbasep).
enable_window(?wbaser).
enable_window(?wbases).
enable_window(?w5).
enable_window(?wmain).
```

```
  enable_window(?b1).
  enable_window(?b2).
  enable_window(?b3).
  enable_window(?b4).
  enable_window(?b5).
  enable_window(?b6).
  enable_window(?b7).
 Show_window(?wbaser).
 set_title(?wbasep,'').
end.
```

(* General Categories Procedure *)

```
Topic search1().

hide_window(?base1).
hide_window(?base2).
hide_window(?base3).
hide_window(?base4).
enable_window(?wbasep).
enable_window(?wbaser).
set_active_window(?wbasep).
set_display_window(?wbasep).

 bmpdbf1 = load_bitmap ('fol1.bmp').
 bmpdbf2 = load_bitmap ('fol2.bmp').
 bmpdbf3 = load_bitmap ('fol3.bmp').
 bmpdbf4 = load_bitmap ('cancelu.bmp').
 if ?first_time2  is 'true' then
  new (bas1, GraphicButton, [?bmpdbf1,dbf1,1,1]) and
  new (bas2, GraphicButton, [?bmpdbf3,dbf2,9.8,1]) and
  new (bas3, GraphicButton, [?bmpdbf2,dbf3,9.8+8.8,1])and
  new (bas4, GraphicButton, [?bmpdbf4,dbf4,9.8+8.8,6]) and
  first_time2 is true
  else
   show_window(?bas1) and
   show_window(?bas2) and
   show_window(?bas3) and
   show_window(?bas4).
```

(* Cancel *)

```
topic dbf4().
hide_window(?bas1).
hide_window(?bas2).
hide_window(?bas3).
hide_window(?bas4).
enable_window(?wbasep).
enable_window(?wbaser).
enable_window(?wbases).
enable_window(?w5).
enable_window(?wmain).
```

```
  enable_window(?b1).
  enable_window(?b2).
  enable_window(?b3).
  enable_window(?b4).
  enable_window(?b5).
  enable_window(?b6).
  enable_window(?b7).
 Show_window(?wbaser).
 set_title(?wbasep,'').

end.

(* Serach in Piles.dbf *)

Topic dbf1().
hide_window(?bas1).
hide_window(?bas2).
hide_window(?bas3).
hide_window(?bas4).
WhichFile is 'piles.dbf'.
cfgfile is 'pilescfg.dbf'.
NewTitle is 'PILES'.
dbf().
end.

(* Serach in Bridge.dbf *)

Topic dbf2().
hide_window(?bas1).
hide_window(?bas2).
hide_window(?bas3).
hide_window(?bas4).
WhichFile is 'bridge.dbf'.
cfgfile is 'bridcfg.dbf'.
NewTitle is 'BRIDGE DECK'.
DBF().
end.

(* Serach in General.dbf *)

Topic dbf3().
hide_window(?bas1).
hide_window(?bas2).
hide_window(?bas3).
hide_window(?bas4).
WhichFile is 'general.dbf'.
cfgfile is 'genecfg.dbf'.
NewTitle is 'GENERAL CONCRETE'.
dbf().
end.
end. (* end General Categories *)
```

```
( Related Topics Search *)

Topic search2().
hide_window(?base1).
hide_window(?base2).
hide_window(?base3).
hide_window(?base4).
wait(,0).
(* set_active_window(?wbatata).
 show_window(?wbatata,8).*)
set_active_window(?wmain).
set_display_window(?wmain).
 show_window(?wmain).
 set_active_window(?wbases).
 set_display_window(?wbases).
Last_list is [].
 do(related).
q is 1.
  LAST_LIST IS sort(?last_list,UP,ascii).
  SET_DISPLAY_POS(2,1).
  IF list_length(?LAST_LIST) IS 0 THEN MESSAGET() ELSE
repeat
  q is ?q+1 and
  text('#m#l', first(?last_list),'#m   ') and
  last_list  is rest(?last_list)
until ?last_list is [].
   enable_window(?b1).
   enable_window(?b2).
   enable_window(?b3).
   enable_window(?b4).
   enable_window(?b5).
   enable_window(?b6).
   enable_window(?b7).
   enable_window(?wbases).
   enable_window(?w5).
  show_window(?wbaser).

(* Error Message *)
topic MessageT().
   D IS WINDOW( ,1.54,3.4,56.3,26.3,'SORRY
!!',[child,siblings,showChildren,visible,thinframe,titlebar],?WBATATA,,LIGHTGRAY,,).
   TEXT('

  IN REACH has determined that this topic is either too general or

   too specific, and has therefore terminated the "Related Topics"

   routine based on the lack of credible results.

             Please wait a moment, and IN REACH will return

              you back to the topic from where you just came.').
```

```
  WAIT(,11).
  CLOSE_WINDOW(?D).
 enable_window(?wmain).
 set_display_window(?wmain).
end.

end. (* Related Topics Search *)

(* -  Search List of topics ---- *)
topic Search.
hide_window(?base1).
hide_window(?base2).
hide_window(?base3).
hide_window(?base4).

   SearchList is ?Savelist.
   wSearch is window ( ,1,4.6,(?col-32), (?row)*0.95,'Search By  "List of
Topics"',[popup,thinFrame,titleBar,showChildren],?WBATATA).
     text ('
        Select a topic from the list below or type the
    topic name, and then click on the "GO TO" button').
   bGoTo is button2 ( 'GO TO', GoTo, 7, 22.5, 12,1.5 ).
   bCancel is button2 ( CANCEL, Cancel, 27, 22.5,12,1.5 ).
  show_window ( ?wSearch ).
  cb1 is combo_box (?searchList, GoTo, 4.75,4.8,,17,'', [simple,sort,vertscroll], double_click_event).
  set_focus (?cb1).

  topic GoTo.
  enable_window(?b1).
   enable_window(?b2).
   enable_window(?b3).
   enable_window(?b4).
   enable_window(?b5).
   enable_window(?b6).
   enable_window(?b7).
  enable_window(?wmain).
  enable_window(?wbases).
  enable_window(?wbasep).
  enable_window(?w5).
   searchText is get_combo_box (?cb1).
   if ?searchText is [] then
      exit ().
   close_window(?wsearch).
   Show_window(?wbaser).
 x = string_where(?searchtext, 'Illustration').
 if ?x = 0 then
   vacio is wrap_load_text (dot457,?searchtext) and
    if ?vacio <> [] then
       mark (?searchtext).
if ?x <> 0 then  mark (?searchtext).
    if not (?mark) then
       smallList is [].
```

```
vacio is [].
 end.

 topic Cancel.
   smallList is [].
   close_window (?wSearch).
  enable_window(?b1).
   enable_window(?b2).
   enable_window(?b3).
   enable_window(?b4).
   enable_window(?b5).
   enable_window(?b6).
   enable_window(?b7).
  enable_window(?wmain).
  enable_window(?wbasep).
  enable_window(?wbases).
  enable_window(?wbaser).
  enable_window(?w5).
  Show_window(?wbaser).
  set_title(?wbasep,'').
  end.

end. (* Search *)
end. (* General Search *)
(*******************************************************)

(* General Categories Procedures *)

topic dbf().
Show_window(?wbaser).
enable_window(?wbaser).
set_active_window(?wbaser).
set_display_window(?wbaser).
text('#e').
set_title(?wbaser,?NewTitle).
(*q is 1.
repeat
 move_window(?wbaser,?col-30.2-?q,?row-27.5+14.5) and
 q is ?q + 5
until ?q > ?col-30.2-1.2.
q is 1.
repeat
 move_window(?wbaser,1.2,?row-27.5+14.5-?q) and
 q is ?q + 5
until ?q > ?row-27.5+14.5 +1.2.
 move_window(?wbaser,1,1).
 last_title is concat('Subcategory  [',?NewTitle,']').
set_title(?wbaser,?last_title).
q is 1.
repeat
 resize_window(?wbaser,1.3+30.5+?q,1.3+?q+13.8) and
 q is ?q+3
```

```
until ?q > 7.
q is 1.
repeat
resize_window(?wbaser,1.2+30.5+15+?q,1.2+15+13.8) and
 q is ?q+3
until ?q > 45.*)
move_window(?wbaser,1,1).
resize_window(?wbaser,?col,?row).


gil is [].
 set_display_window (?wbaser).
set_active_window(?wbaser).
hand(gil).

topic hand(managl).
 text(#e).
 managl is [].
 dat_list is [].
 Read_base().

topic read_base.
  filer is concat( 'SELECT  descript FROM ',?cfgfile).
  hstmt = qeExecSQL (?hdbc,?filer).
 if ?hstmt = 0
     then
     window () and
     text ('FILES HAVE BEEN CORRUPTED  !!!', #n, 'please EXIT, and start over') and
     button (EXIT, clear, 15, 6) and
     wait ().
  more ().
 rc is qeendsql(?hstmt).
  dat_nil is [].
   adi is button2 ( '  INSTRUCTIONS  ',inst, 60, 27.5, 18,1.5 ).
   ad is button2 ( 'GO ', add, 2.77, 27.5, 10,1.5 ).
  USE_FONT(?BOLDFONT).
  SET_DISPLAY_POS(2.77,2.5).
  text('Subjects').
  use_font (?mainFont, [Window,Control]).
  box1 is [].
  box1 is list_box (?dat_list,add, 2.75,3.8,,23.8,T,T, double_click_event).
  res_list is ['FDOT Standard Specs (1991)','FDOT Supplemental Specs (1994)','FDOT Standard Drawings
(1994)','FDOT CPAM Manual (1993)','FDOT Inspection Manual-Part 3 (1990)','FDOT Tricks of The Trade
(1993)','FDOT Inspection Checklists (1995)','FDOT PPR Lessons Learned (1995)','UF PCC Lessons Learned
(1995)','CRSI Placing Rebar (1993)'].
  USE_FONT(?BOLDFONT).
   SET_DISPLAY_POS(42.77,3.8).
  text('Sources').
  USE_FONT(?mainFont, [Window,Control]).
  boxl is [].
  boxl is list_box (?res_list,add, 42.5,4.8,,14,,T, double_click_event).
```

```
topic add().
 hide_window(?ad).
 RES_EXIT IS [].
 RES_LIST IS GET_LIST_BOX(?BOXL).
 CLOSE_WINDOW(?BOXL).
  IF ONE_OF(?RES_LIST,'FDOT Standard Specs (1991)') THEN RES_EXIT GETS 'R1'.
  IF ONE_OF(?RES_LIST,'FDOT Supplemental Specs (1994)') THEN RES_EXIT GETS 'R2'.
  IF ONE_OF(?RES_LIST,'FDOT Standard Drawings (1994)') THEN RES_EXIT GETS 'R6'.
  IF ONE_OF(?RES_LIST,'FDOT CPAM Manual (1993)') THEN RES_EXIT GETS 'R5'.
  IF ONE_OF(?RES_LIST,'FDOT Inspection Manual-Part 3 (1990)') THEN RES_EXIT GETS 'R7'.
  IF ONE_OF(?RES_LIST,'FDOT Tricks of The Trade (1993)') THEN RES_EXIT GETS 'R4'.
  IF ONE_OF(?RES_LIST,'FDOT Inspection Checklists (1995)') THEN RES_EXIT GETS 'R3'.
  IF ONE_OF(?RES_LIST,'FDOT PPR Lessons Learned (1995)') THEN RES_EXIT GETS 'R9'.
  IF ONE_OF(?RES_LIST,'UF PCC Lessons Learned (1995)') THEN RES_EXIT GETS 'R10'.
  IF ONE_OF(?RES_LIST,'CRSI Placing Rebar (1993)') THEN RES_EXIT GETS 'R8'.
  IF RES_LIST IS [] THEN RES_EXIT IS [].
 data_nil is get_list_box(?box1).

 pat is [].
ult is last(?data_nil).
dat_list is [].
 field2 is [].
   apply(burn,?data_nil).
    largo is list_length(?dat_list).
if ?largo = 0 then
 List_Full is concat('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ') else
  List_Full is concat('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',first(?dat_list),'= .T.').


if list_length(?dat_list)<>0 then
repeat
  List_Full is concat(?List_Full,' and ',first(?dat_list),'= .T.') and
  dat_list is rest(?dat_list)
until ?Dat_list is [].


if list_LENGTH(?RES_EXIT)<>0 then
 if ?largo = 0 then List_Full is concat(?List_Full,first(?res_exit),'= .T.')
  else List_Full is concat(?List_Full,' and ',first(?res_exit),'= .T.').



manag is [].
 hstmt = qeExecSQL(?hdbc,?List_Full).
  while  (qeFetchNext (?hstmt) = 0) then
 PAT = get_string (qeValChar (?hstmt, 1, , )) and
 manag gets ?pat.
 rc is qeendsql(?hstmt).

 Tii is button2 ( 'TRY AGAIN', try, 42.75, 27.5, 13,1.5 ).
 pii is button2 ( 'CONTINUE', cont, 60, 25, 18,1.5 ).
 aii is button2 ( 'ALL', All, 42.75, 25, 13,1.5 ).
```

```
 dii is button2 ( 'CLEAR', Clear, 42.75, 25, 13,1.5 ).
 hide_window(?dii).
  USE_FONT(?BOLDFONT).
   SET_DISPLAY_POS(42.77,2.5).
  text('Result#40s#41 of Search').
  USE_FONT(?mainFont, [Window,Control]).
 box2 is [].
 box2 is list_box (?manag,cont, 42.75,3.8,30,20,T,T, double_click_event).
 exit().
end.


topic inst().
 ins_ac IS WINDOW(,39,2.6,48.5,21.6,, [child, siblings,thinframe, showChildren,visible], ?wbaser,,,).
  USE_FONT(?BOLDFONT).
  SET_DISPLAY_POS(2,1.3).
  text('                    INSTRUCTIONS#l').
  USE_FONT(?mainFont).
  SET_DISPLAY_POS(2,2.9).
  text(' 1.- Select one or more items from the
      list of "Subjects".

  2.- If you want to search through #fred ALL#f  Sources,
      then simply click on the "GO" button.

  3.- If you want to search through only #fred ONE#f  Source,
      select desired item from the list of "Sources"
      and then click on the "GO" button.

  4.- If results are not satisfactory, you can restart the
      search by clicking on the "TRY AGAIN" button.

  5.- If results are satisfactory, select one or more
      topics from the "Result#40s#41 of Search" list, or
      choose all topics by clicking on the "ALL" button.

  6.- To return selected topics back to the IN REACH
      work area click on the "CONTINUE" button.').
    button ('  OK  ', Continue, 43,1 ) and
   wait ().

close_window(?ins_ac).
end.

topic try().
Close_window(?tii).
Close_window(?dii).
Close_window(?aii).
Close_window(?pii).
Close_window(?box1).
Close_window(?box2).
```

```
Hand().
exit().
end.

topic all().
 set_list_box(?box2,?manag).
 Hide_window(?aii).
 show_window(?dii).
end.

topic clear().
 close_window(?box2).
 box2 is list_box (?manag,cont,42.75,3.8,30,20,T,T,double_click_event).
 Hide_window(?dii).
 show_window(?aii).
end.
end.

topic burn(lisi1).
   field2 is first(?lisi1).
   sqlstmt is concat('SELECT field FROM ',?cfgfile,' where descript = trim("',?field2,'")').
   hstmt = qeExecSQL (?hdbc,?sqlstmt).
   RetCode = qeFetchnext (?hstmt).
   pAT = get_string (qeValChar (?hstmt, 1, , )).
  dat_list gets ?pat.
  lisi1 is rest(?lisi1).
  rc is qeendsql(?hstmt).
end.

topic ok_ay().
     window ().
     text ('no se que pasa', #n, ?SQLstmt).
     button (OK, Continue, 10, 6).
     wait ().
end.

topic more().
   while  (qeFetchNext (?hstmt) = 0) then
      get_data ().
 end.

topic get_data().
 dat is get_record(1).
 dat_list gets ?dat.

topic get_record (count).
  get_record = get_string (qeValChar (?hstmt, ?count, '', 0)).
  end. (* get_record *)
end.

end.
end. (* End General Categories *)
```

```
(* Write in general categories windows *)

topic cont().

 hide_window(?wbasep).
 manag is get_list_box(?box2).
 close_window(?box1).
 close_window(?box2).
 close_window(?ad).
 close_window(?aii).
 close_window(?dii).
 close_window(?pii).
 resize_window(?wbaser,30.5,9).
 move_window(?wbaser,?col-30.2,?row-27.75+10.7).
 set_active_window(?wbatata).
 show_window(?wbatata,8).
 set_active_window(?wbaser).
 set_display_window(?wbaser).
 q is 1.
  if ?manag is [] then namet is 'Search By' else namet is 'Result(s) of Search'.
 set_title(?wbaser,?namet).
text(#e).
 SET_DISPLAY_POS(2,1).

repeat
 q is ?q+1 and
  text('#m#l', first(?manag),'#m   ') and
  manag is rest(?manag)
 until ?manag is [].
   enable_window(?b1).
   enable_window(?b2).
   enable_window(?b3).
   enable_window(?b4).
   enable_window(?b5).
   enable_window(?b6).
   enable_window(?b5).
  enable_window(?wmain).
  enable_window(?wbasep).
  enable_window(?wbases).
  enable_window(?w5).
EXIT().
end.


(* Initialize Main Screen *)
topic init().
  filesearch is 'search.rap'.
  SaveList is wrap_load_text(?filesearch,lista).
  smalllist is [].
  searchlist is [].
  helvSmall is create_char_font ( [0.82,0.71428,700,F,F,F,0,1,34,helv]).
  mainFont is create_char_font ( [1,1,400,'F','F','F',0,1,34,'Helv']).
```

```
 boldFont is create_char_font ( [1,1,700,'F','F','F',0,1,34,'Helv']).
 wmain is window (,1.1,3.3,(?col-32), (?row)*0.89, , [child, siblings,thinframe, vertScroll, showChildren,
visible], ?wbatata,,lightgray,).
 show_window(?wmain).
  use_font (?mainFont, [Window,Control]).
  use_font (?mainFont, [Window,Control]).
 ICON IS LOAD_ICON('INREACH.ICO').
 attach_icon ( ?wBATATA, ?icon ).

end. (* End Init *)

(* End Main Program *)
```

```
(*****************************************************)
(*              RELATED TOPICS SUBROUTINE           *)
(*                                                   *)
(*****************************************************)
(*           Select information from related topics  *)
(*                                                   *)
(*****************************************************)

topic related().

(* Set variables *)

 set_active_window(?wbases).
 set_display_window(?wbases).
 text('#e').
 ff is ''.
 pilesl is 'topic_desc,a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v'.
 pilesf is [a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v].
 concretel is 'topic_desc,a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u'.
 concretef is [a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u].
 bridgel is 'topic_desc,a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q'.
 bridgef is [a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q].
 quat is 1.
  general is [].
  control is 1.

(* read record from database piles.dbf *)

  whichfile is 'piles.dbf'.
   longer is concat ('SELECT ',?pilesl,' FROM ',?whichfile,' WHERE topic_desc= ''',last(?antes),'''').
   hstmt = qeExecSQL (?hdbc ,?longer).
   whichfile is 'pilescfg.dbf' and
   while  (qeFetchNext (?hstmt) = 0) then
   apply(extract,?pilesf).
  rc is qeendsql(?hstmt).
 quat is 1.
 if ?general is [] then
  control is 2 and

(* read record from database general.dbf *)

    whichfile is 'general.dbf' and
     longer is concat ('SELECT ',?concretel,' FROM ',?whichfile,' WHERE topic_desc= ''',last(?antes),'''') and
     hstmt = qeExecSQL (?hdbc ,?longer) and
   whichfile is 'genecfg.dbf' and
   while  (qeFetchNext (?hstmt) = 0) then
  apply(extracta,?concretef).
  rc is qeendsql(?hstmt).
   quat is 1.
   if ?general is [] then
  control is 3 and
```

```
(* read record from database bridge.dbf *)

   whichfile is 'bridge.dbf' and
    longer is concat ('SELECT ',?bridgel,' FROM ',?whichfile,' WHERE topic_desc= "',last(?antes),'"') and
    hstmt = qeExecSQL (?hdbc ,?longer) and
  whichfile is 'bridcfg.dbf' and
   while  (qeFetchNext (?hstmt) = 0) then
  apply(extractb,?bridgef).
  rc = qeendsql(?hstmt).

(* if list is empty return to main program *)

 if ?general is [] then exit().

(* look for fields in each database *)

 quat is 1.
 gen_list is [].
 apply(extract2,?general).

 whichfile is 'pilescfg.dbf'.
 quat is 1.
 general0 is [].
 ff is ''.
 apply(extract5,?gen_list).

 whichfile is 'bridcfg.dbf'.
 quat is 1.
 general1 is [].
 ff is ''.
 apply(extract3,?gen_list).

 whichfile is 'genecfg.dbf'.
 quat is 1.
 general2 is [].
 ff is ''.
 apply(extract4,?gen_list).

if ?control is 1 then count is list_length(?general0).
if ?control is 2 then count is list_length(?general2).
if ?control is 3 then count is list_length(?general1).
 quat is 1.

(*  look for final information in Piles.dbf *)

general is ?general0.
  Whichfile is 'piles.dbf'.
  if ?count is 1  then Message().
  if ?count is 2 then if ?control is 1 then Look2() else        message().
  if ?count is 3 then if ?control is 1 then Look3() else        exact().
  if ?count is 4 then Look4().
  if ?count is 5 then if ?control is 1 then Look5() else        lookx().
  if ?count is 6 then Look6().
```

```
(* look for final information in General.dbf *)

 Whichfile is 'general.dbf'.
 general is ?general2.

 if ?count is 1 then Message().
 if ?count is 2 then if ?control is 2 then Look2() else      message().
 if ?count is 3 then if ?control is 2 then Look3() else      exact().
 if ?count is 4 then Look4().
 if ?count is 5 then if ?control is 2 then Look5() else      lookx().
 if ?count is 6 then Look6().

(* look for final information in Bridge.dbf *)

 Whichfile is 'bridge.dbf'.
 general is ?general1.
 if ?count is 1 then Message().
 if ?count is 2 then if ?control is 3 then Look2() else      message().
 if ?count is 3 then if ?control is 3 then Look3() else      exact().
 if ?count is 4 then Look4().
 if ?count is 5 then if ?control is 3 then Look5() else      lookx().
 if ?count is 6 then Look6().

(* clear final list *)

 enable_window(?wbases).
 solo is different(?last_list,?antes).
 last_list is ?solo.
 LAST_LIST IS sort(?last_list,up,ascii).
 Temporary  is ?last_list.
 Temporary2  is ?last_list.
 c is [].
 repeat
   b is first(?last_list) and
   c is different(?last_list,?b) and
   c gets ?b and
   last_list is [] and
   last_list is ?c and
   temporary is rest(?temporary) and
   c is []
 until ?temporary is [].


 enable_window(?wmain).
 enable_window(?wbasep).
 enable_window(?wbases).
 enable_window(?w5).
(* clear all *)
 general is [].
 control is 1.
 whichfile is ''.
  longer is ''.
 quat is 1.
 gen_list is [].
```

```
 general0 is [].
 general1 is [].
 general2 is [].
  ff is ''.

(* end of related *)


(* Look for 2 combinations *)

Topic Look2().

  ff is ''.
  longer is ''.
  longer is concat ('SELECT TOPIC_DESC FROM ',?whichfile,' WHERE ',element(?general,1),' = .T. and
',element(?general,2),' = .T.').
 quat is ?quat +1.
   hstmt = qeExecSQL (?hdbc ,?longer).
  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
end.

(* Look for 3 combinations *)

Topic Look3().
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T.').
 quat is ?quat +1.
   hstmt = qeExecSQL (?hdbc ,?longer).
  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T.'). quat is ?quat +1.
   hstmt = qeExecSQL (?hdbc ,?longer).
  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  ff is ''.
  rc is qeendsql(?hstmt).
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T.').
 quat is ?quat +1.
   hstmt = qeExecSQL (?hdbc ,?longer).
  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
end.
```

```
(* Look for 4 combinations *)

Topic Look4().
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T.and ',element(?general,3),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T.and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T.and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T.and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
end.

(* Look for 5 combinations *)

Topic Look5().
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T.').
 quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
```

```
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).
while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
rc is qeendsql(?hstmt).
ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,3),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
ff is ''.
rc is qeendsql(?hstmt).
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
ff is ''.
rc is qeendsql(?hstmt).
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
rc is qeendsql(?hstmt).
ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,4),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
rc is qeendsql(?hstmt).
ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).
```

```
  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,5),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
end.

(* Look for 6 combinations *)


Topic Look6().
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T. and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

  while  (qeFetchNext (?hstmt) = 0) then
  ff is get_rec(1) and last_list gets ?ff.
  rc is qeendsql(?hstmt).
  ff is ''.
  longer is ''.
  longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T. and ',element(?general,5),' = .T.').
```

```
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,4),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
```

```
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T. and ',element(?general,5),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T. and ',element(?general,6),' = .T.').
quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
 ff is ''.
 longer is ''.
```

```
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,3),' = .T.
and ',element(?general,4),' = .T. and ',element(?general,5),' = .T. and ',element(?general,6),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
end.

(* look for 2 combinations *)

topic exact().
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T.').
 quat is ?quat +1.
 hstmt = qeExecSQL (?hdbc ,?longer).

 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1) and last_list gets ?ff.
 rc is qeendsql(?hstmt).
end.

(* look for 3 combinations *)

topic lookx().
 ff is ''.
 longer is ''.
 longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T.and ',element(?general,4),' = .T.').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
```

```
while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.


ff is ''.
rc is qeendsql(?hstmt).
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,3),' = .T.and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.

rc is qeendsql(?hstmt).

ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,3),' = .T. and ',element(?general,4),' = .T.and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.

rc is qeendsql(?hstmt).

ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,2),' = .T.
and ',element(?general,3),' = .T.and ',element(?general,4),' = .T.and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
rc is qeendsql(?hstmt).

ff is ''.
longer is ''.
longer is concat ('SELECT TRIM(TOPIC_DESC) FROM ',?whichfile,' WHERE ',element(?general,1),' = .T.
and ',element(?general,2),' = .T. and ',element(?general,4),' = .T.and ',element(?general,5),' = .T.').
quat is ?quat +1.
hstmt = qeExecSQL (?hdbc ,?longer).

while (qeFetchNext (?hstmt) = 0) then
ff is get_rec(1) and last_list gets ?ff.
rc is qeendsql(?hstmt).


end.
```

```
topic Message().
end.

(* read final information from each database *)

topic extract5().

 longer is ''.
 longer is concat ('SELECT field FROM ',?whichfile,' WHERE descript= "',element(?gen_list,?quat),'"').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1).
 if ?ff <> '' then general0 gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
end.

topic extract4().
 longer is ''.
 longer is concat ('SELECT field FROM ',?whichfile,' WHERE descript= "',element(?gen_list,?quat),'"').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1).
 if ?ff <> '' then general2 gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
end.

topic extract3().
 longer is ''.
 longer is concat ('SELECT field FROM ',?whichfile,' WHERE descript= "',element(?gen_list,?quat),'"').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1).
 if ?ff <> '' then general1 gets ?ff.
 ff is ''.
 rc is qeendsql(?hstmt).
end.

topic extract2().
 longer is ''.
 longer is concat ('SELECT descript FROM ',?whichfile,' WHERE field= "',element(?general,?quat),'"').
 quat is ?quat +1.
  hstmt = qeExecSQL (?hdbc ,?longer).
 while  (qeFetchNext (?hstmt) = 0) then
 ff is get_rec(1).
 gen_list gets ?ff.
 rc is qeendsql(?hstmt).
end.
```

```
topic extract().
 quat is ?quat +1.
 rfield is get_rec(?quat).
 if ?rfield is '1' then rfield is element(?PILESF,?quat-1) and general gets ?rfield.
end.
topic extractb().
 quat is ?quat +1.
 rfield is get_rec(?quat).
 if ?rfield is '1' then rfield is element(?bridgef,?quat-1) and general gets ?rfield.
end.
topic extracta().
 quat is ?quat +1.
 rfield is get_rec(?quat).
 if ?rfield is '1' then rfield is element(?concretef,?quat-1) and general gets ?rfield.
end.


(* get records from database *)


topic get_rec (count).
  get_rec = get_string (qeValChar (?hstmt, ?count, '', 0)).
   end. (* get_record *)

end. (* end of related topics *)
```

APPENDIX N
THE "CLASSIFICATION" AND "CONFIGURATION" DATABASES

BRIDGE DECK CLASSIFICATION DATABASE																												
SUBCATEGORY - Bridge Deck		SUBJECT HEADINGS																	SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	400-5.7 SIP METAL FORMS							T		T			T					T	T									
2	400-5.7.1 general							T		T			T					T	T									
3	400-5.7.2 materials							T		T	T		T						T									
4	400-5.7.3 design							T		T			T					T	T									
5	400-5.7.4 construction							T		T			T					T	T									
6	400-5.7.5 placing concrete	T						T		T		T	T						T									
7	400-5.7.6 inspection							T		T			T			T			T									
8	400-5.8 SIP CONC FORMS							T		T		T						T	T									
9	400-5.8.1 general							T		T		T						T	T									
10	400-5.8.2 materials							T		T	T	T							T									
11	400-5.8.3 design							T		T		T						T	T									
12	400-5.8.4 construction							T		T		T						T	T									
13	400-5.8.5 placing concrete	T						T		T		T							T									
14	400-5.8.6 inspection							T		T		T				T			T									
16	400-7.15 BRIDGE FLOORS	T										T		T				T	T									
17	400-7.15.1 bulkhead/screed	T									T	T		T				T	T									
18	400-7.15.2 design of screed	T				T						T		T				T	T									
19	400-7.15.3 screeding	T										T		T				T	T									
20	400-9.7 Concrete Deck Joint																T		T									
21	400-15.2.5 class 4 finish			T	T							T		T	T			T	T									
22	400-15.2.8 bridge sidewalks			T	T							T					T		T									
23	400-16.2 Cure Bridge Decks		T									T							T									
24	400-17.2 Deck Mtrl Storage		T								T	T							T									
25	415-5.10 Deck Slabs	T					T				T							T	T									
26	415-5.13 Chairs & Bolsters	T					T	T			T								T									
27	710-6.2 Weather Limitations				T						T								T									
28	710-6.3 Surface Preparation				T						T								T									
29	711-1 Description				T						T								T									
30	711-2.2 Sealing Primer				T						T								T									
31	711-4.2 Apply Seal Primer				T	T					T								T									
32	925-2 Membrane Curing		T		T						T	T							T									
33	IC - INSPECT BRIDGE DECK															T					T							
34	IC-Bridge Deck Curing		T								T	T				T					T							
35	IC-Bridge Deck Dry Screed	T					T					T		T		T		T			T							
36	IC-Bridge Deck Form Remvl							T	T							T					T							
37	IC-Bridge Deck Forming							T	T	T						T		T			T							
38	IC-Bridge Deck General Prep															T		T			T							
39	IC-Bridge Deck Grooving			T								T		T	T	T					T							
40	IC-Bridge Deck Place Concrt	T										T				T	T	T			T							
41	IC-Bridge Deck Place Rebar	T					T				T					T					T							
42	IC-Bridge Deck Screed/Finsh	T		T		T						T		T		T					T							
43	CPAM 9-3 Deck Thickness	T					T					T				T		T					T					
44	TOT[IV-20,21,22] Screeding	T		T		T						T		T		T						T						
45	TOT[IV-39] Cure Compound		T		T						T	T				T						T						
46	TOT[IV-44] Armor Joint Void	T										T				T	T					T						
47	Illustration-Metal Bar Chairs	T					T	T			T															T		
48	Illustration-Screed Machine	T		T		T						T		T											T			
49	LL01R9301-Lite Pole Vibratn										T						T										T	
50	LL01R9401-Deck Striping										T	T			T		T										T	

BRIDGE DECK CONFIGURATION DATABASE	
CODES	**SUBJECT HEADINGS**
A	Placement
B	Curing
C	Finishing
D	Surfaces
E	Equipment
F	Rebar
G	Formwork
H	Removal
I	Stay-in-place
J	Materials and Accessories
K	Concrete
L	Metal
M	Screeding
N	Grooving
O	Inspection
P	Special Requirements
Q	General Requirements

GENERAL CONCRETE CLASSIFICATION DATABASE																																
SUBCATEGORY - General Concrete		SUBJECT HEADINGS																				SOURCES										
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	126-4 EXCAVATION																		T			T	T									
2	125-4.1 General Requiremnt				T														T			T	T									
3	125-4.2 Earth Excavation				T														T			T	T									
4	125-4.3 Rock Excavation				T														T			T	T									
5	125-4.4 Trench Excavation						T												T		T		T									
6	400 - CONCRETE STRUCTRS																	T				T	T									
7	400-5 FORMS														T							T	T									
8	400-5.1 General														T							T	T									
9	400-5.2 Inspection/Approval														T					T			T									
10	400-5.3 Non-metallic Forms														T	T	T					T	T									
11	400-5.4 SPECIAL REQMNT														T						T		T									
12	400-5.4.1 re-entrant angles														T						T		T									
13	400-5.4.2 handrails/parapet						T								T						T		T									
14	400-5.4.3 end-bent caps			T											T						T		T									
15	400-5.4.4 footings				T										T						T		T									
16	400-5.5 Form Align / Braces														T		T					T	T									
17	400-5.6 Prep & Cleaning														T							T	T									
18	400-7 PLACE CONCRETE							T										T				T	T									
19	400-7.1.1 cold concreting							T										T			T		T									
20	400-7.1.2 hot concreting							T										T			T		T									
21	400-7.2 Light Requirements							T										T			T		T									
22	400-7.3 Placing Inspections							T										T		T			T									
23	400-7.4 Exposure to Water							T										T			T		T									
24	400-7.5 General Requirmnts							T										T				T	T									
25	400-7.6 Belt Conveyor Place							T					T					T					T									
26	400-7.7 Placing by Pumping							T					T					T					T									
27	400-7.8 Consolidation							T	T									T				T	T									
28	400-7.9 Obstructions							T	T									T				T	T									
29	400-7.10 Successive Layers							T										T			T		T									
30	400-7.11 Concrete Vibration							T	T				T					T					T									
31	400-7.12 Columns		T					T										T					T									
32	400-7.13 SLABS	T						T										T				T	T									
33	400-7.13.1 finishing device	T						T			T		T					T				T	T									
34	400-7.13.2 placing operation	T						T										T				T	T									
35	400-7.13.4 intermediate web	T		T			T	T										T			T		T									
36	400-7.13.5 weather protect	T						T										T			T		T									
37	400-7.14 Deck Girders	T		T				T										T			T		T									
38	400-7.16 Box Culverts						T	T										T					T									
39	400-16 FINISH CONCRETE										T	T						T				T	T									
40	400-15.1 General Finish										T	T						T				T	T									
41	400-15.2.1 general										T	T						T				T	T									
42	400-15.2.2 class 1 finish										T	T						T			T		T									
43	400-15.2.3 class 2 finish										T	T						T			T		T									
44	400-15.2.4 class 3 finish										T	T						T			T		T									
45	400-15.2.6 CLASS 6 FINISH										T	T						T			T		T									

GENERAL CONCRETE CLASSIFICATION DATABASE																																
SUBCATEGORY - General Concrete		SUBJECT HEADINGS																					SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
46	400-15.2.6.1 general										T	T						T			T		T									
47	400-15.2.6.2 material										T	T					T	T			T		T									
48	400-15.2.6.3 surface prep										T	T						T			T		T									
49	400-15.2.6.4 application										T	T						T			T		T									
50	400-15.2.6.5 finish product										T	T						T			T		T									
51	400-15.2.6.6 color										T	T						T			T		T									
52	400-15.2.6.7 tests & certify										T	T						T			T		T									
53	400-15.2.7 asphalt concrete										T	T						T			T		T									
54	400-16 CURE CONCRETE									T								T				T	T									
55	400-16.1.1 curing time									T								T				T	T									
56	400-16.1.2 curing methods									T								T				T	T									
57	400-16.3 Cure Constrct Joint									T								T			T		T									
58	415 - REINFORCING STEEL													T								T	T									
59	415-3 Protection of Material													T			T					T	T									
60	415-4 Bend, Splice & Cut							T						T								T	T									
61	415-5 PLACE & FASTEN							T						T								T	T									
62	415-5.1 Bar Space - General							T						T								T	T									
63	415-5.2 Blocks for Spacing							T						T			T				T		T									
64	415-5.3 Wire for Tying							T						T			T				T		T									
65	415-5.4 Splices							T						T								T	T									
66	415-5.5 Footings				T			T						T									T									
67	415-5.6 Column/Wall Dowel		T		T	T		T						T									T									
68	415-5.7 Col Verticals/Hoops		T					T						T									T									
69	415-5.8 Wall Steel					T		T						T									T									
70	415-5.9 Beams and Caps			T				T						T									T									
71	415-5.11 Box Culverts						T	T						T									T									
72	415-5.12 Cleaning							T						T								T	T									
73	521 - BARRIER WALLS					T												T				T	T									
74	521-1 Barrier Description					T												T				T	T									
75	521-3.1 Stationary Forming					T					T	T			T			T					T									
76	521-3.2 Slip Forming					T					T	T			T			T					T									
77	521-4 Barrier Curing					T				T								T					T									
78	521-5.1 Joints, General					T												T			T		T									
79	521-5.2 Contraction Joints					T												T			T		T									
80	521-5.3 Expansion Joints					T												T			T		T									
81	346-3.3 Mass Concrete																	T			T			T								
82	400-14 Removal of Forms														T	T								T								
83	929 - FLY ASH CONCRETE																T	T			T			T								
84	929-1.1 General Requirmnts																T	T			T			T								
85	929-2.1 Source Approval																T	T			T			T								
86	929-3.1 Special Requiremnts																T	T			T			T								
87	929-4.1 Exceptions																T	T			T			T								
88	929-5.1 Acceptance Testing																T	T			T			T								

GENERAL CONCRETE CLASSIFICATION DATABASE																																
SUBCATEGORY - General Concrete		SUBJECT HEADINGS																					SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
89	IC - INSPECTING CONCRETE																	T		T		T			T							
90	IC-Concrete Curing									T								T		T		T			T							
91	IC-Concrete Final Finishing										T							T		T		T			T							
92	IC-Concrete Form Removal														T	T				T		T			T							
93	IC-Concrete Forming														T	T				T		T			T							
94	IC-Concrete General Prep																	T		T		T			T							
95	IC-Concrete Pile Footing Prep				T													T	T	T		T			T							
96	IC-CONCRETE PLACEMENT							T										T		T		T			T							
97	IC-Belt Conveyor Placement							T					T					T		T					T							
98	IC-Night Placement							T										T		T	T				T							
99	IC-Placement by Pumping							T					T					T		T					T							
100	IC-Placement in Columns		T					T										T		T					T							
101	IC-Placement in Slabs	T						T										T		T					T							
102	IC-Placement Inspections							T										T		T		T			T							
103	IC-Placement Requirements							T										T		T		T			T							
104	IC-Successive Layers							T										T		T	T				T							
105	IC-Temperature Restrictions							T										T		T	T				T							
106	IC-Vibration Requirements							T	T									T		T					T							
107	IC-Weather Protection							T										T		T	T				T							
108	IC-CONCRETE REBAR							T						T						T		T			T							
109	IC-Barrier Rebar Placement					T		T						T						T					T							
110	IC-Beam/Cap Rebar Placement			T				T						T						T					T							
111	IC-Column Rebar Placement		T					T						T						T					T							
112	IC-Footing Rebar Placement				T			T						T						T					T							
113	IC-General Rebar Placement							T						T						T		T			T							
114	IC-Wall Rebar Placement					T		T						T						T					T							
115	TOT[IV-3] Vibrate Concrete							T	T									T		T						T						
116	Illustration-Bar Identification							T						T								T								T		
117	Illustration-Table of Bar Size							T						T								T								T		
118	LL01C9502-Pile Cap Elevatn			T	T													T			T											T
119	LL01R9402-Barier Wall Crck					T											T	T			T										T	
120	400-7.13.3 steel span decks	T						T										T			T		T									
121	LL01C9503-Concrete Classes			T			T	T								T		T														T
122	346-3.1(a) concrete classes							T								T		T				T		T								

GENERAL CONCRETE CONFIGURATION DATABASE	
CODES	**SUBJECT HEADINGS**
A	Slabs
B	Columns
C	Beams and Caps
D	Footings and Foundations
E	Walls and Barriers
F	Misc. Structural Components
G	Placement
H	Vibration
I	Curing
J	Finishing
K	Surfaces
L	Equipment
M	Rebar
N	Formwork
O	Removal
P	Materials and Accessories
Q	Concrete
R	Excavation
S	Inspection
T	Special Requirements
U	General Requirements

PILES CLASSIFICATION DATABASE																																	
SUBCATEGORY - Piles		SUBJECT HEADINGS																						SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	4-3.2.1 changes in work										T												T	T									
2	4-4 Unforeseeable Work										T												T	T									
3	455 - PILING																						T	T									
4	455-1 Description																						T	T									
5	455-2 Classification																						T	T									
6	455-3 GEN REQUIREMENT																						T	T									
7	455-3.1 Foundation Piling																			T			T	T									
8	455-3.2 Bearing															T							T	T									
9	455-3.3 Bearing Formulas															T							T	T									
10	455-3.4 Pile Lengths									T													T	T									
11	455-3.5 Penetration															T				T			T	T									
12	455-3.6 End Bent/Abutment													T	T							T	T	T									
13	455-3.7 Lead/Follow/Temp													T			T						T	T									
14	455-3.8 Predrill Pile Holes								T						T								T	T									
15	455-3.9 Driving Variation													T						T		T	T	T									
16	455-3.10 Water Jets												T	T			T						T	T									
17	455-3.11 Pile Hammers													T			T						T	T									
18	455-4 TIMBER PILING		T																				T	T									
19	455-4.1 Description		T																				T	T									
20	455-4.2 Materials		T				T																	T									
21	455-4.3 Driving Preparation		T				T							T					T					T									
22	455-4.4 Driving Hammers		T											T			T							T									
23	455-4.5 Method of Driving		T										T	T		T	T							T									
24	455-4.6 Storage & Handling		T																				T	T									
25	455-4.7 Cutting Off		T																				T	T									
26	455-4.8 Pile Heads		T				T												T					T									
27	455-5 PRESTRESS / COMP			T		T																	T	T									
28	455-5.1 Description			T		T																	T	T									
29	455-5.2 Materials			T		T	T																	T									
30	455-5.3 Manufacture			T		T																	T	T									
31	455-5.4 Forms			T		T																T		T									
32	455-5.5 Casting			T		T													T			T		T									
33	455-5.6 Finish			T		T																T		T									
34	455-5.7 Curing			T		T																T		T									
35	455-5.8 Storage & Handling			T		T																	T	T									
36	455-5.9 Driving Preparation			T		T								T										T									
37	455-5.10 Method of Driving			T		T							T	T			T		T					T									
38	455-5.11 Driving Equipment			T		T	T							T			T							T									
39	455-5.12 Extension/Buildup			T		T												T						T									
40	455-6 STEEL PILING	T																					T	T									
41	455-6.1 Description	T																					T	T									
42	455-6.2 Material	T					T																	T									
43	455-6.3 Pile Splices	T																T						T									
44	455-6.4 Welding	T																T						T									
45	455-6.5 Pile Heads & Tips	T																	T					T									
46	455-6.6 Pile Bent Bracing	T					T															T		T									
47	455-6.7 Driving Equipment	T												T			T		T					T									
48	455-6.8 Painting	T					T															T		T									

PILES CLASSIFICATION DATABASE

SUBCATEGORY - Piles		SUBJECT HEADINGS																						SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
49	455-7 TEST PILES / LOADS								T														T	T									
50	455-7.1 Description								T														T	T									
51	455-7.2 Pile/Load Location								T														T	T									
52	455-7.3 Materials						T		T															T									
53	455-7.4 Driving Hammers								T					T			T							T									
54	455-7.5 Method of Testing								T				T	T			T						T	T									
55	455-7.6 Pile/Load Disposal								T														T	T									
56	455-8 CIP CONCRETE				T	T	T																T	T									
57	455-8.1 Description				T	T																	T	T									
58	455-8.2 Length / Dimension				T	T				T														T									
59	455-8.3 Driving				T	T	T							T			T							T									
60	455-8.4 Predrilling				T	T									T									T									
61	455-8.5 Concrete for Piles				T	T	T																	T									
62	455-8.6 Reinforcement				T	T													T					T									
63	455-8.7 Inspection				T	T															T			T									
64	455-8.8 Splices				T	T												T						T									
65	455-9 SHEET PILING							T															T	T									
66	455-9.1 Description							T															T	T									
67	455-9.2 Materials						T	T															T	T									
68	455-9.3 Timber Sheet Piling		T					T											T				T	T									
69	455-9.4 Steel Sheet Piling	T						T															T	T									
70	455-9.5 Concrete Sheet Pile					T	T	T															T	T									
71	455-10 PREFORMED HOLE											T											T	T									
72	455-10.1 Description											T											T	T									
73	455-10.2 Use of Pile Holes											T											T	T									
74	455-10.3 Payment Condition										T	T												T									
75	455-10.4 Construct Methods							T				T				T								T									
76	455-11 MEASUREMENT									T													T	T									
77	455-11.1 Timber Piling		T							T														T									
78	455-11.2 Prestress/Compos			T		T				T								T						T									
79	455-11.2.6 cut-off build-ups			T		T				T								T						T									
80	455-11.3 Steel Piling	T								T									T					T									
81	455-11.4 Test Piles								T	T														T									
82	455-11.5 Test Loads								T	T														T									
83	455-11.6 Timber Sheet Pile		T					T		T														T									
84	455-11.7 Steel Sheet Pile	T						T		T														T									
85	455-11.8 Concrt Sheet Pile					T		T		T														T									
86	455-11.9 Preformed Holes									T		T												T									
87	455-11.10 Pile Splices									T								T						T									
88	455-11.11 CIP Concrete Pile				T	T				T														T									
89	455-12 PAYMENT BASIS										T												T	T									
90	455-12.1 Timber Piling		T								T													T									
91	455-12.2 Prestress/Compos			T		T					T													T									
92	455-12.3 Steel Piling	T									T													T									
93	455-12.4 Test Piles								T		T													T									
94	455-12.5 Test Loads								T		T													T									
95	455-12.6 Timber Sheet Pile		T					T			T													T									
96	455-12.7 Steel Sheet Pile	T						T			T													T									

PILES CLASSIFICATION DATABASE																																	
SUBCATEGORY - Piles		SUBJECT HEADINGS																						SOURCES									
Node #	Node Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
97	455-12.8 Concrt Sheet Pile					T		T			T													T									
98	455-12.9 Preformed Holes										T	T												T									
99	455-12.10 Pile Splices										T							T						T									
100	455-12.11 CIP Concrete Pile				T	T					T													T									
101	455-12.12 General Payment										T												T	T									
102	460-6 Welds	T																T						T									
103	A455-3.1 Protect Existing													T								T		T	T								
104	A455-3.2.1 excavation																			T			T		T								
105	A455-3.3.2 diesel hammers													T			T						T		T								
106	A455-3.10.3 pay conditions										T	T													T								
107	A455-3.11.4 set-check/drive													T								T	T		T								
108	A455-3.17 DRIVE TOLRANCE													T								T	T		T								
109	A455-3.17.1 general													T								T	T		T								
110	A455-3.17.2 position													T								T	T		T								
111	A455-3.17.3 axial alignment													T								T	T		T								
112	A455-3.17.4 elevation													T								T	T		T								
113	A455-3.17.5 tolrance deviate													T						T		T	T		T								
114	A455-8 Pile Installation Plan													T			T						T		T								
115	IC - INSPECTING PILES																				T		T			T							
116	IC-Pile Driving													T							T	T	T			T							
117	IC-Pile Field Preparation																				T		T			T							
118	IC-Pile Inspection Wrap-up																				T		T			T							
119	IC-Pile Office Preparation																				T		T			T							
120	IC-Pile Placement											T	T								T		T			T							
121	IC-Pile Preformed Holes											T									T		T			T							
122	IC-Pile Splices & Buildups	T		T		T															T		T			T							
123	CPAM 9-1 Pile Drive Criteria													T			T						T					T					
124	TOT IV-1.2 Drive Precst Pile			T		T								T					T		T		T				T						
125	LL01C9501-Pile Tolerances			T		T								T						T		T	T										T
126	Illustration-Precst Pile Splice			T		T												T											T				
127	Illustration-Pile Driving Form													T			T						T					T					

PILES CONFIGURATION DATABASE

CODES	SUBJECT HEADINGS
A	Steel
B	Timber
C	Prestress and Composite
D	Cast-in-Place
E	Concrete
F	Materials and Accessories
G	Sheet Piles
H	Test Piles and Loads
I	Measurement
J	Payment
K	Preformed Holes
L	Jetting
M	Driving
N	Predrilled Holes
O	Bearing
P	Equipment
Q	Splices and Buildups
R	Head and Tips
S	Footings and Foundations
T	Inspection
U	Special Requirements
V	General Requirements

APPENDIX O
IN REACH TESTING COVER LETTER AND COMMENT SHEET

COLLEGE
OF
ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA 32611
DEPARTMENT CHAIRMAN
AREA CODE 904 PHONE 392-9537
STUDENT RECORDS
AREA CODE 904 PHONE 392-0933

Date:

Reviewer's Name
Reviewer's Title
Reviewer's Organization
Address of Organization

RE: Software Review of the IN REACH prototype system

Dear Reviewer:

Enclosed, are the four diskettes containing the IN REACH prototype system, along with a comment sheet to record your impressions of IN REACH upon completion of your review. If there is anyone else at your office who wants to review IN REACH, please feel free to give them a copy of the diskettes and comment sheet. If you experience any difficulties installing or running IN REACH, please do not hesitate to give me a call at (904) 392 - 2560. Additionally, my FAX number is (904) 392 - 3394 for returning your completed Reviewer's Comment Sheet.

INSTRUCTIONS FOR INSTALLING AND RUNNING IN REACH:

1. Create a subdirectory within the root directory (for example c:\ INREACH>) of your hard drive.
2. Copy all files on all 4 disks directly into this new subdirectory (IN REACH requires 4.42 meg on your hard drive).
3. From the Windows "File Manager",open up the IN REACH subdirectory, and double click on the executable file (INREACH.EXE) to initialize the program.

SPECIAL NOTES:

1. If you get any type of system, window or programming error during IN REACH operations, or the mouse becomes unresponsive, i.e. the cursor does not change from the standard arrow head to the index finger when passed across a hypertexed word (green underlined text), the best course of action at this point is to completely exit IN REACH and reinitialize from the Windows "File Manager" by double clicking on the INREACH.EXE file. One exception to the mouse not responding is when you click on the "Search By" button. As you will see, when you click "Search By", IN REACH is waiting for you to search and the hypertext links are temporarily deactivated.

Page - 2
Date:

SPECIAL NOTES (cont.):

2. From the Welcome screen of IN REACH, you can click on the "INTRODUCTION" button to view a brief preview screen of the basic layout and general functions of IN REACH.

3. Currently, only the General Category of BRIDGES is operational, the other 5 General Category buttons are in place for future developmental purposes. Additionally, please note that at this point within the General Category of BRIDGES, the concentration of the knowledge base is on new bridge construction with a focus on inspection operations associated with, for now, only the Subcategories of Piles, Bridge Decks, and General Concrete. As this system is only in the prototype stage, it required a very limited focus to start with.

4. When selecting "Subjects" to search within one of the 3 available Subcategories (Piles, Bridge Deck or General Concrete), keep in mind that the search is based on Boolean "AND" queries. What this means is that if, for example, you select the three subject areas of "Slabs", "Rebar" and "Placement" within the Subcategory of "General Concrete", IN REACH will only return those topics which are specifically linked to at least all three of these subjects. What this implies is that you should start off your searches more general and then get more specific.

Enjoy your foray into the world of IN REACH and again I want to encourage you to please contact me if you experience any problems. Also I would like to take this opportunity to thank you for your continued efforts in helping use develop the IN REACH prototype system.

Sincerely, Bill Epstein

William C. Epstein, P.E.

IN REACH
REVIEWER'S COMMENT SHEET

DATE: ________

I. REVIEWER'S GENERAL INFORMATION

Name: ______________________________

Employer: ______________________________

District of Normal Operations: ______________________________

Years of Highway Construction Experience: ______________________________

Title: ______________________________

Description of Duties: ______________________________

____

II. COMMENTS

A. Based on the choices below, please select the most appropriate response that reflects your personal opinion with respect to the level of **"user-friendliness"** demonstrated by the IN REACH prototype system that you have been asked to review.

___ **Superior**
___ **Above Average**
___ **Average**
___ **Below Average**
___ **Poor**

B. Assuming that the knowledge base (i.e, the number of topic screens) could be unlimitedly expanded, what is your personal opinion of the effectiveness of the methods IN REACH represents with respect to organizing, accessing and relating highway construction knowledge and information.

___ **Superior**
___ **Above Average**
___ **Average**
___ **Below Average**
___ **Poor**

UF PCC-LL (Sheet 2)
No. 95 __ __

III. LESSON LEARNED

Problem Backround: ______________________________

Problem Resolution: ______________________________

Special Notes: ______________________________

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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